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(54) **DEVICE AND METHOD FOR REMOTE VESSEL LIGATION**

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Related U.S. Application Data

(63) Continuation of application No. 09/521,279, filed on Mar. 7, 2000, now Pat. No. 6,348,037, which is a continuation of application No. 09/200,218, filed on Nov. 25, 1998, now Pat. No. 6,162,173, which is a continuation-in-part of application No. 09/102,723, filed on Jun. 22, 1998, now Pat. No. 5,895,353.

(51) **Int. Cl.**⁷ **A61B 17/02**

(52) **U.S. Cl.** **600/206; 600/235**

(58) **Field of Search** 606/204, 205, 606/206, 201, 210, 235, 159

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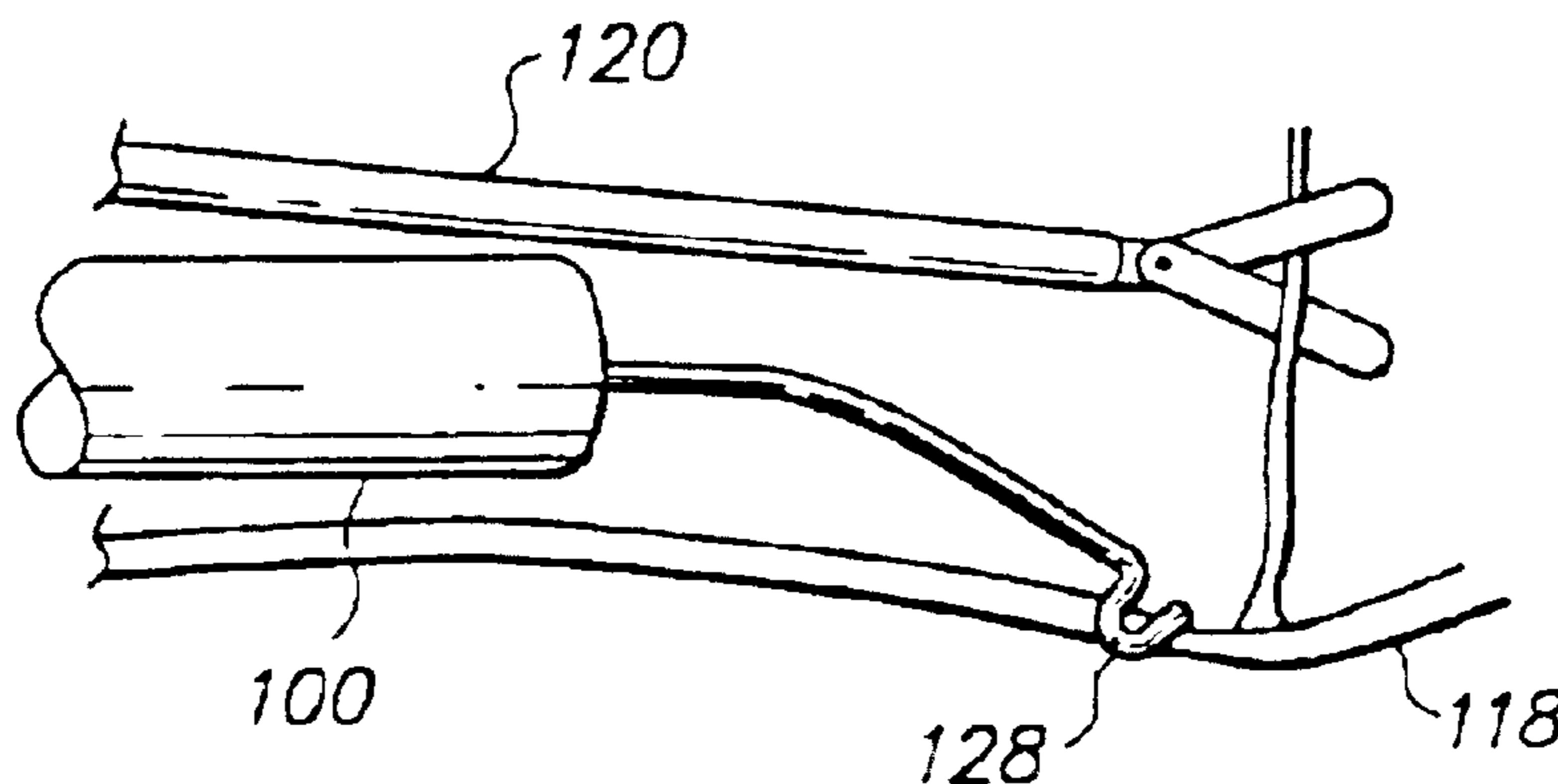
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(57) **ABSTRACT**

A retractor and a surgical tool are positioned at the distal end of the cannula. A dissection cradle is located at the distal end of a distal portion of the retractor that is resiliently skewed relative to the cannula axis, and includes two substantially parallel, spaced legs with the retractor shaped in a loop therebetween. The procedure includes locating a vessel and side branch of interest and extending the retractor to retain the vessel in the dissection cradle to urge the vessel away from the axis of the cannula in order to isolate a side branch for exposure to the surgical tool.

9 Claims, 13 Drawing Sheets



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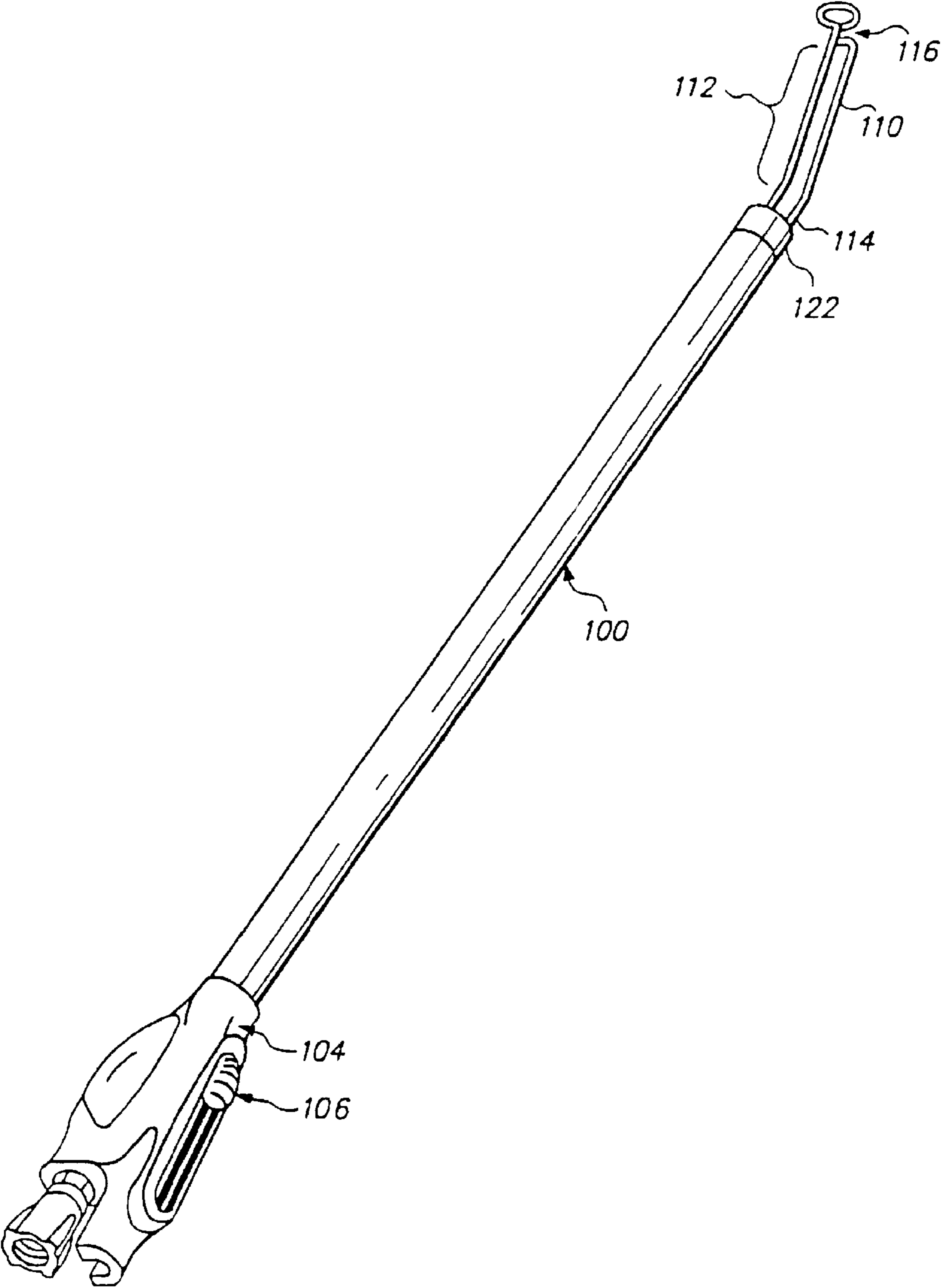


FIG. 1

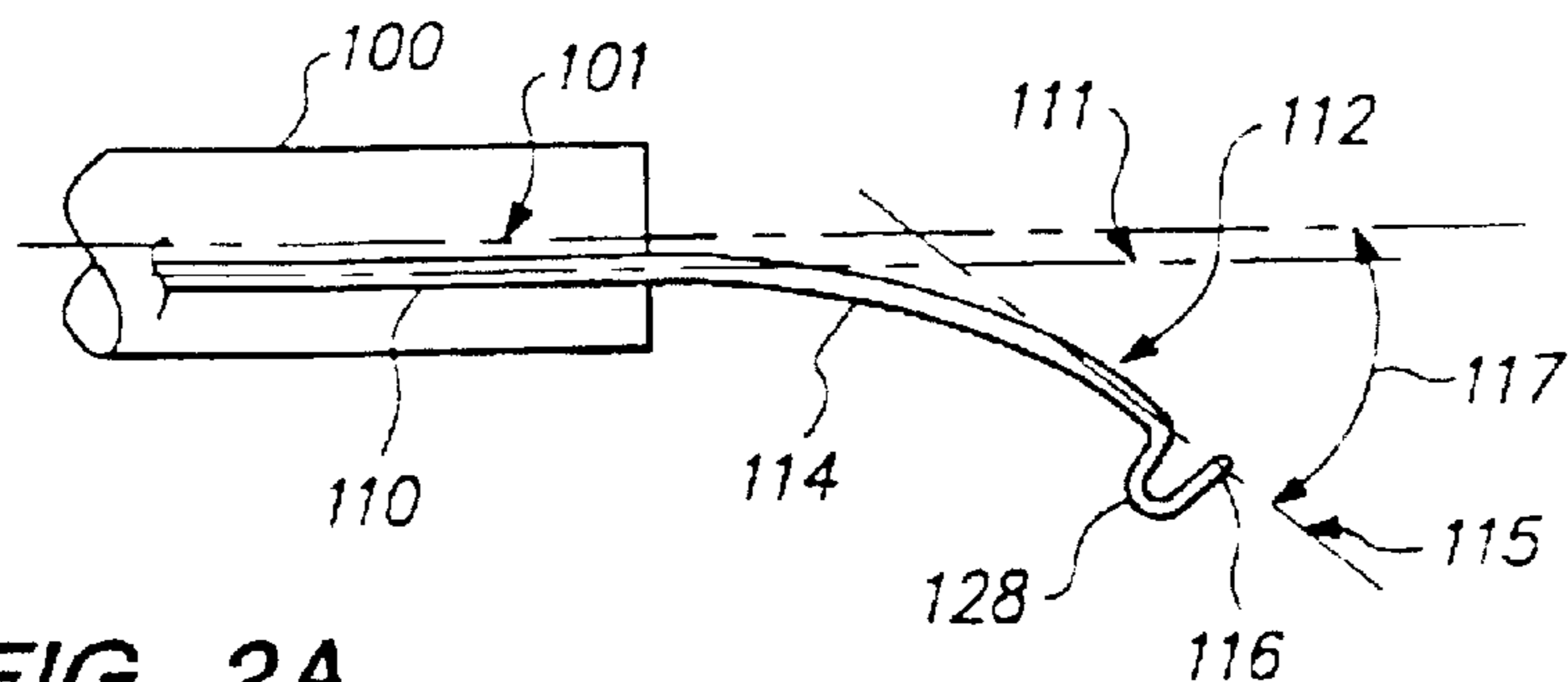


FIG. 2A

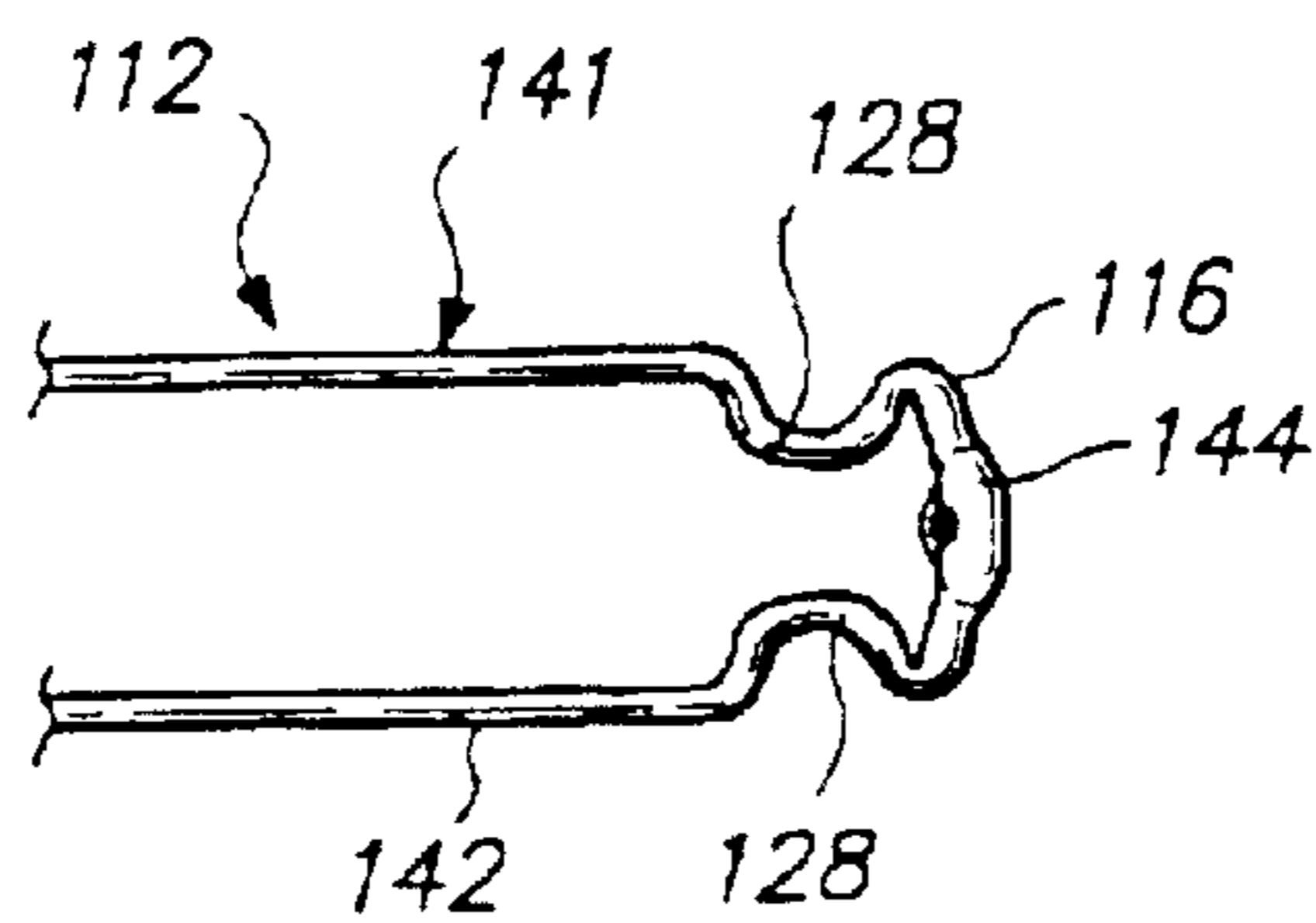


FIG. 2B

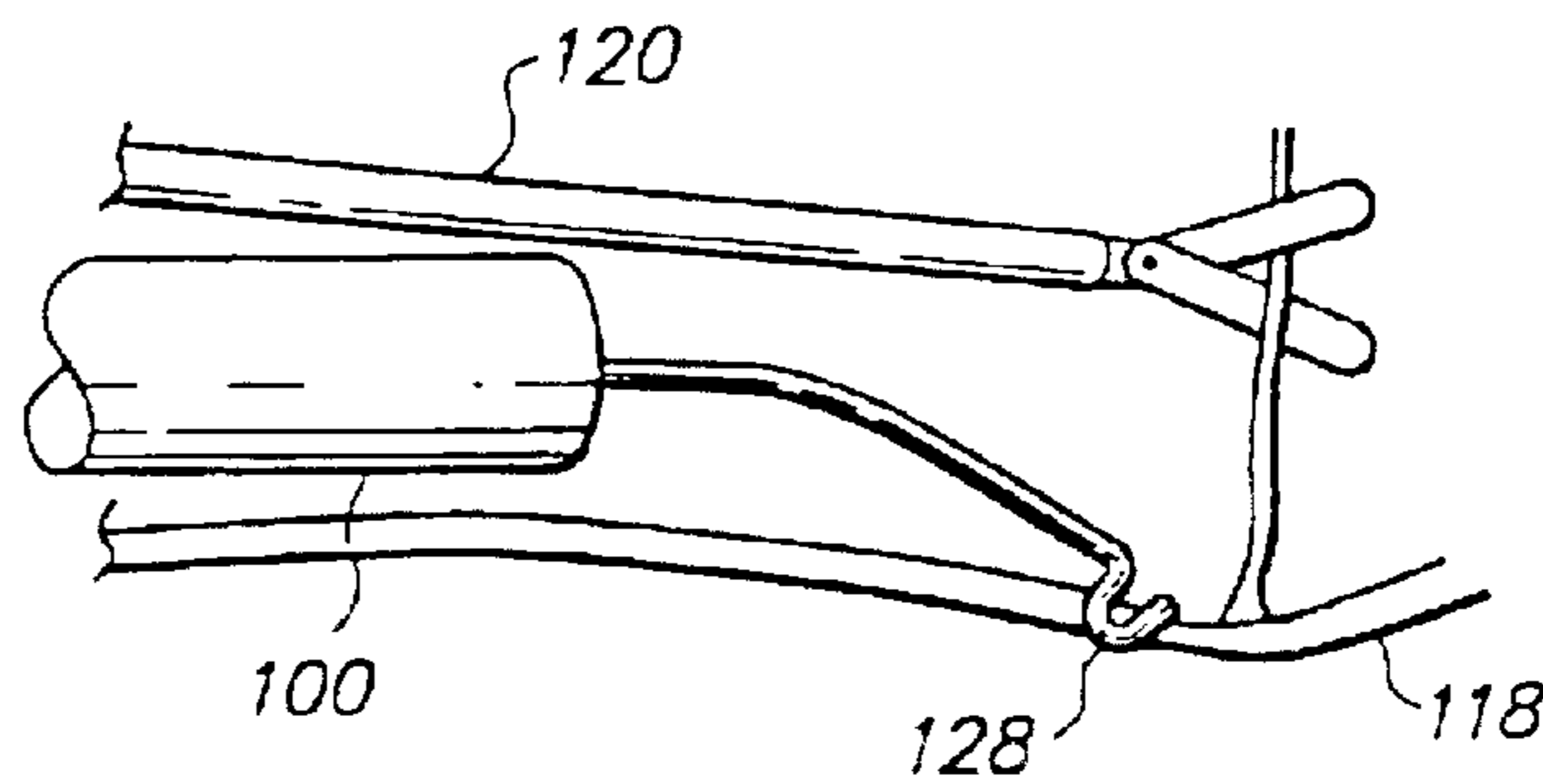


FIG. 3A

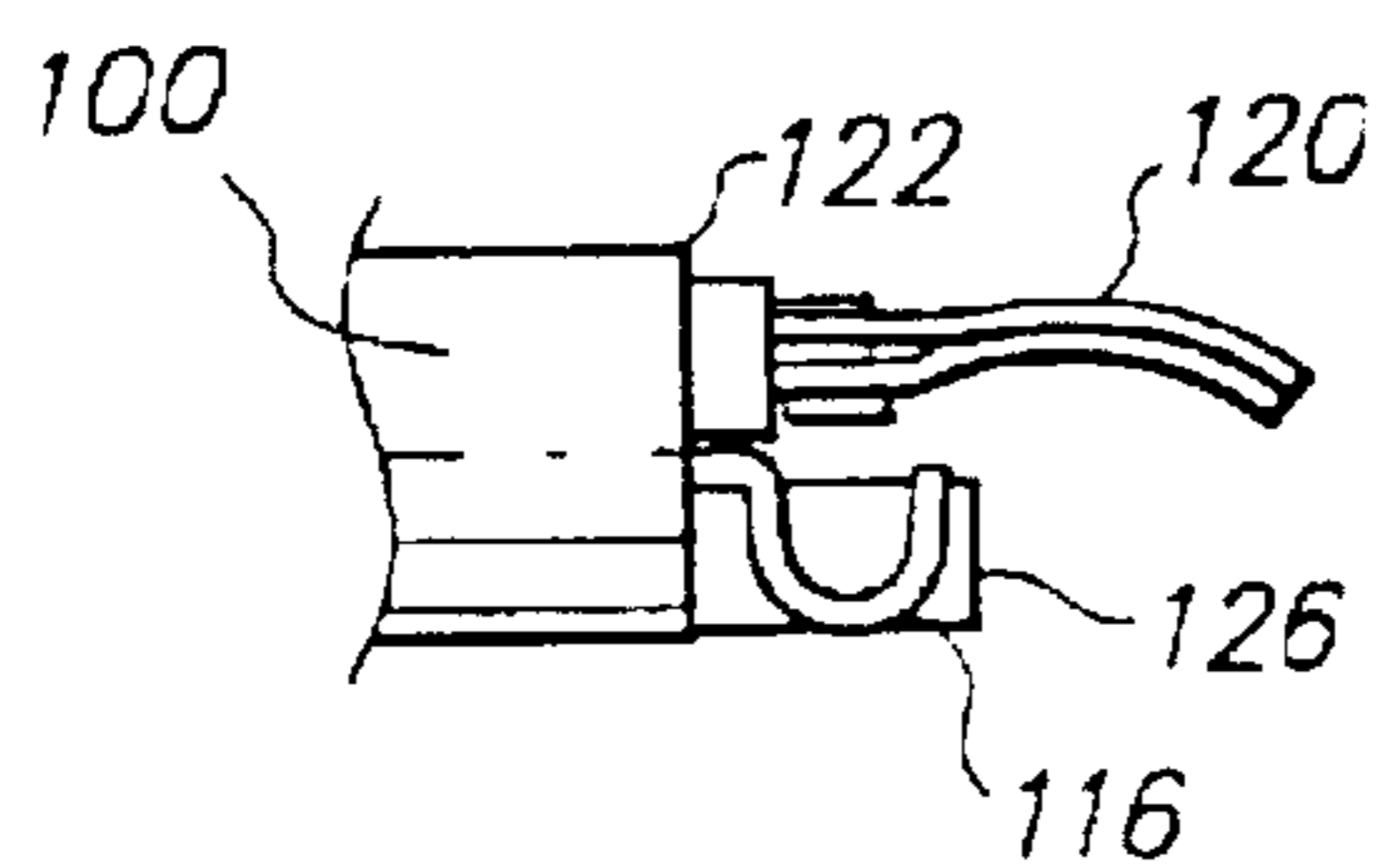


FIG. 3B

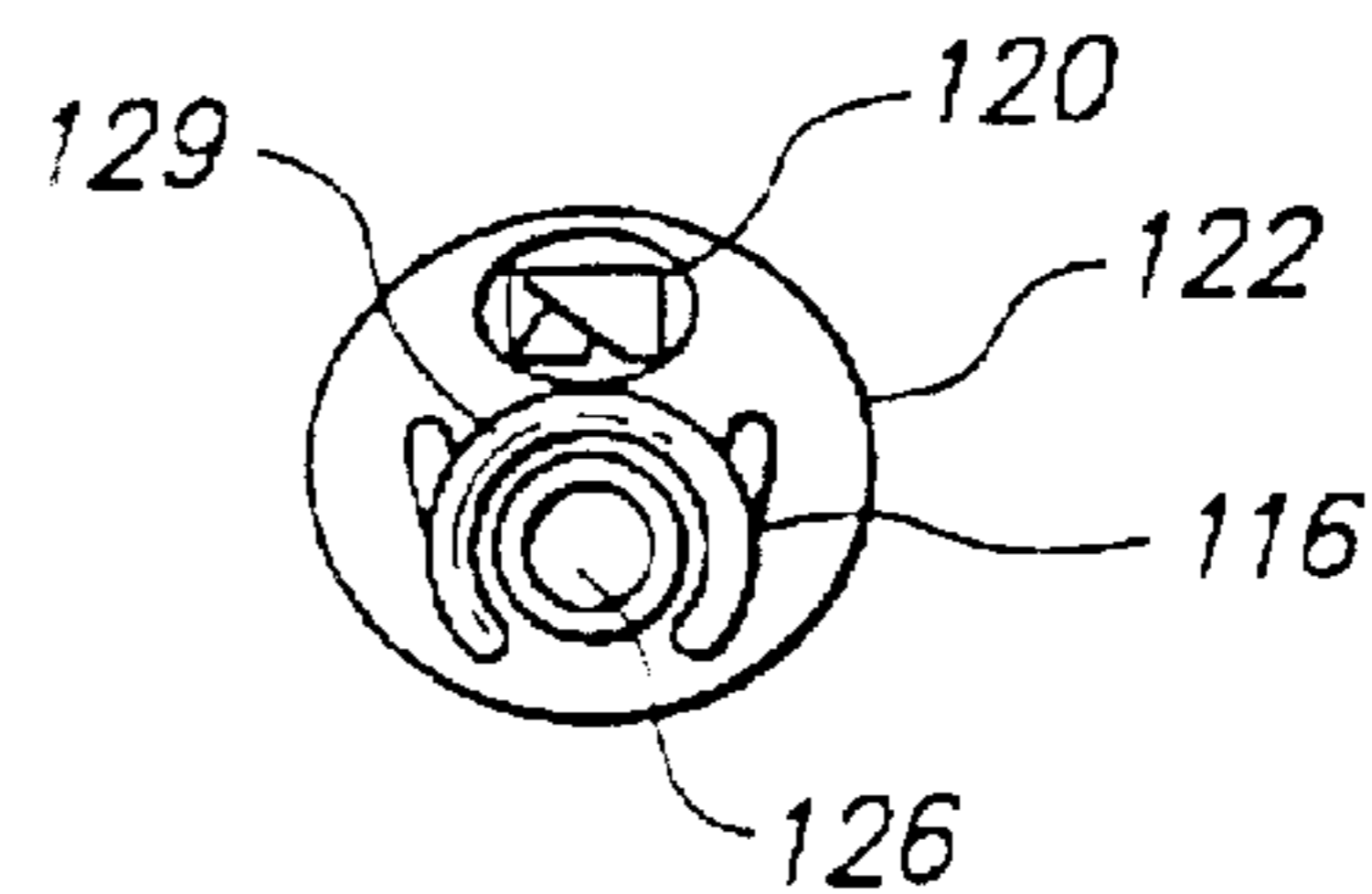


FIG. 3C

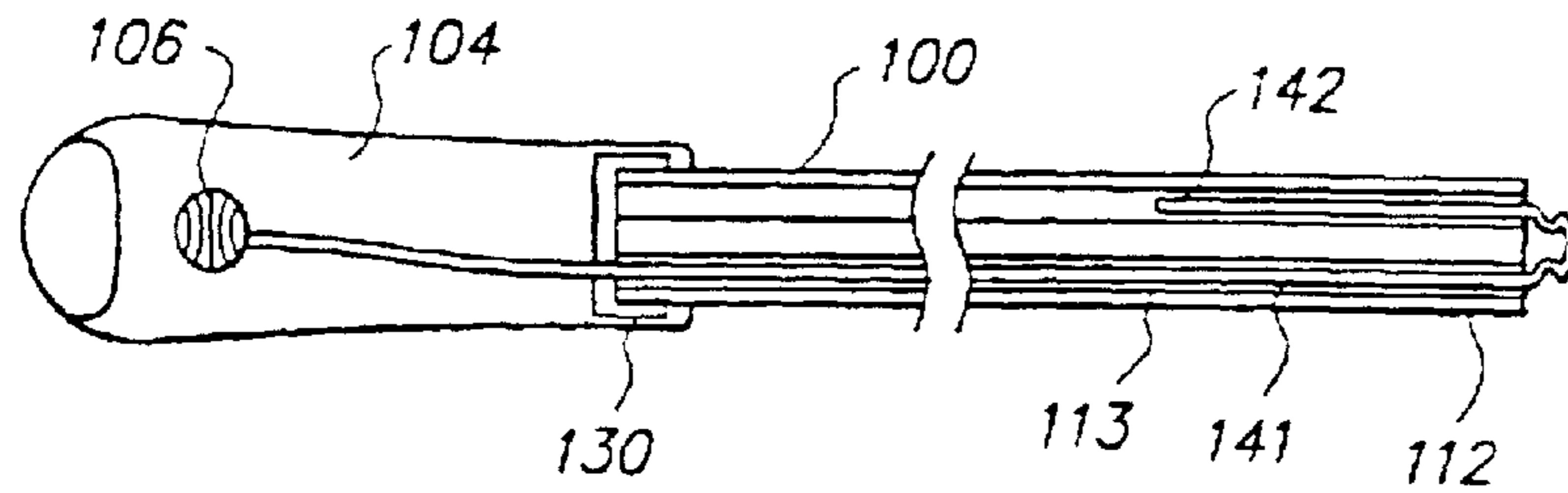


FIG. 4A

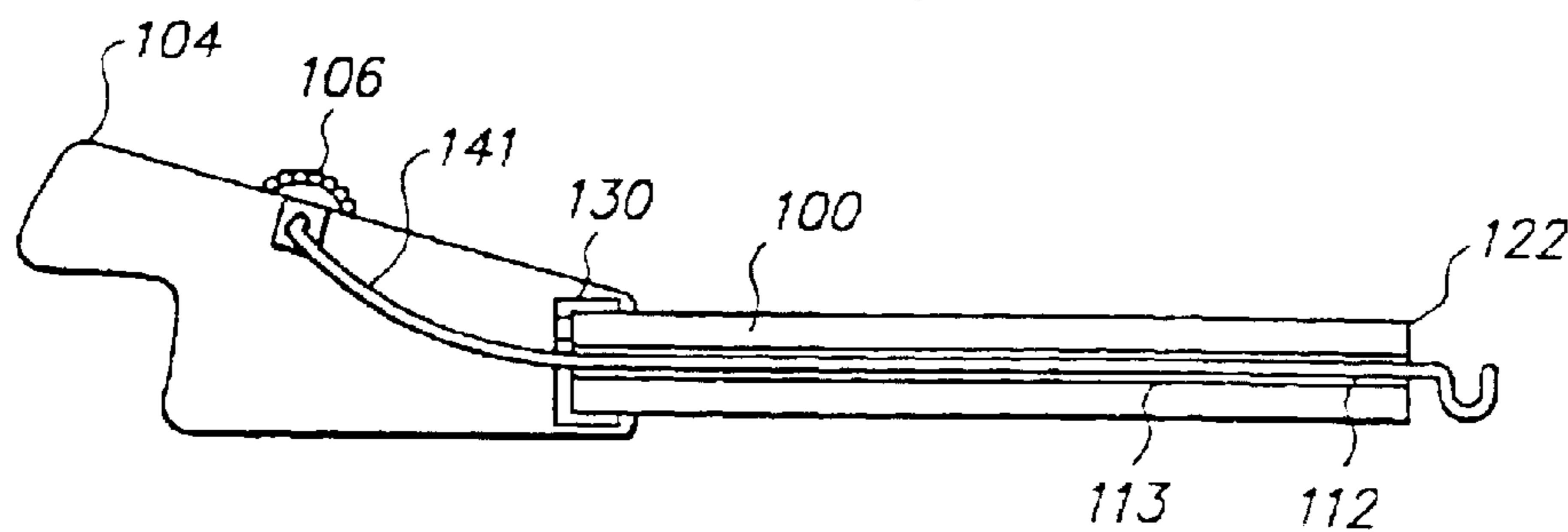


FIG. 4B

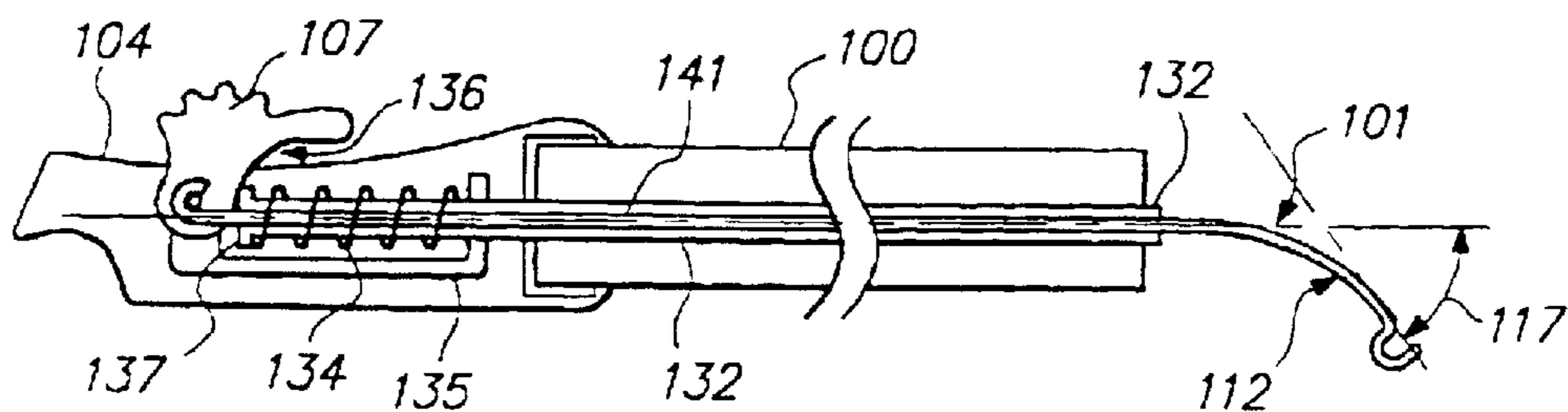


FIG. 5A

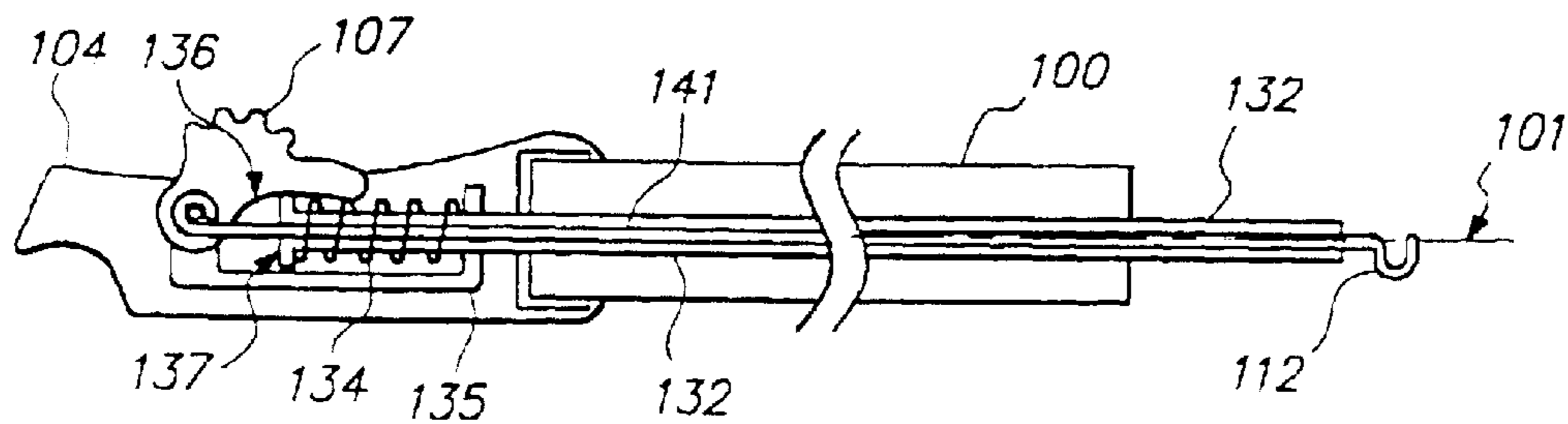


FIG. 5B

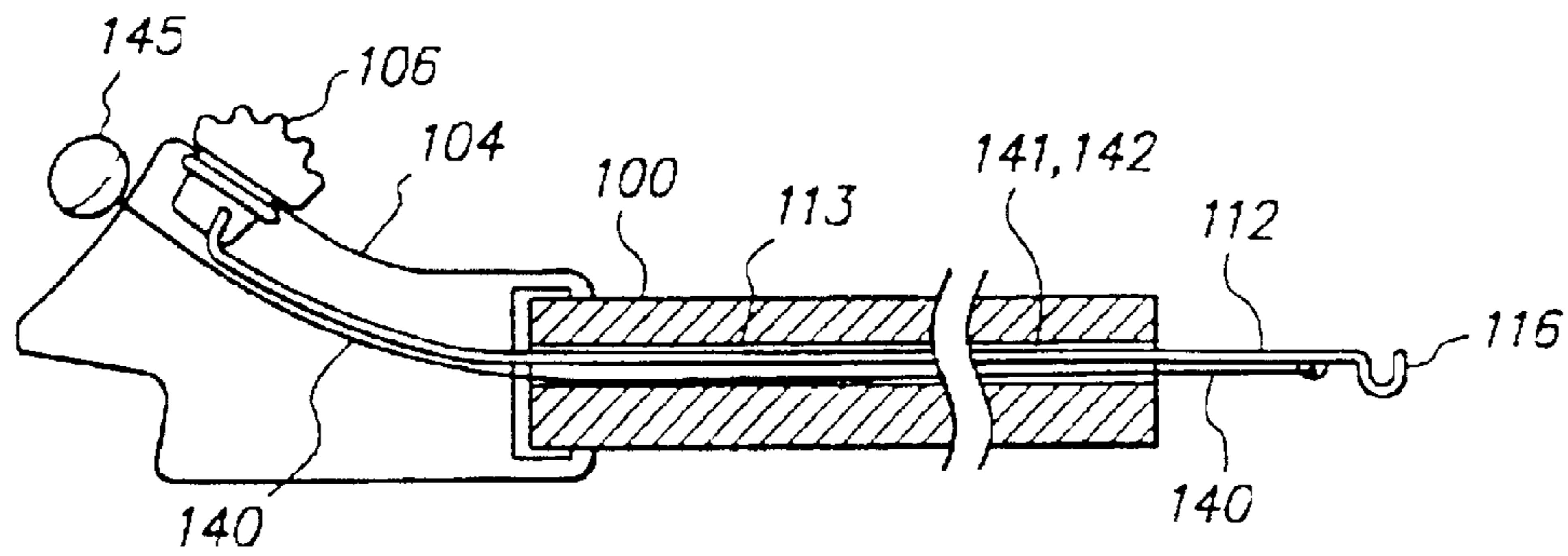


FIG. 6A

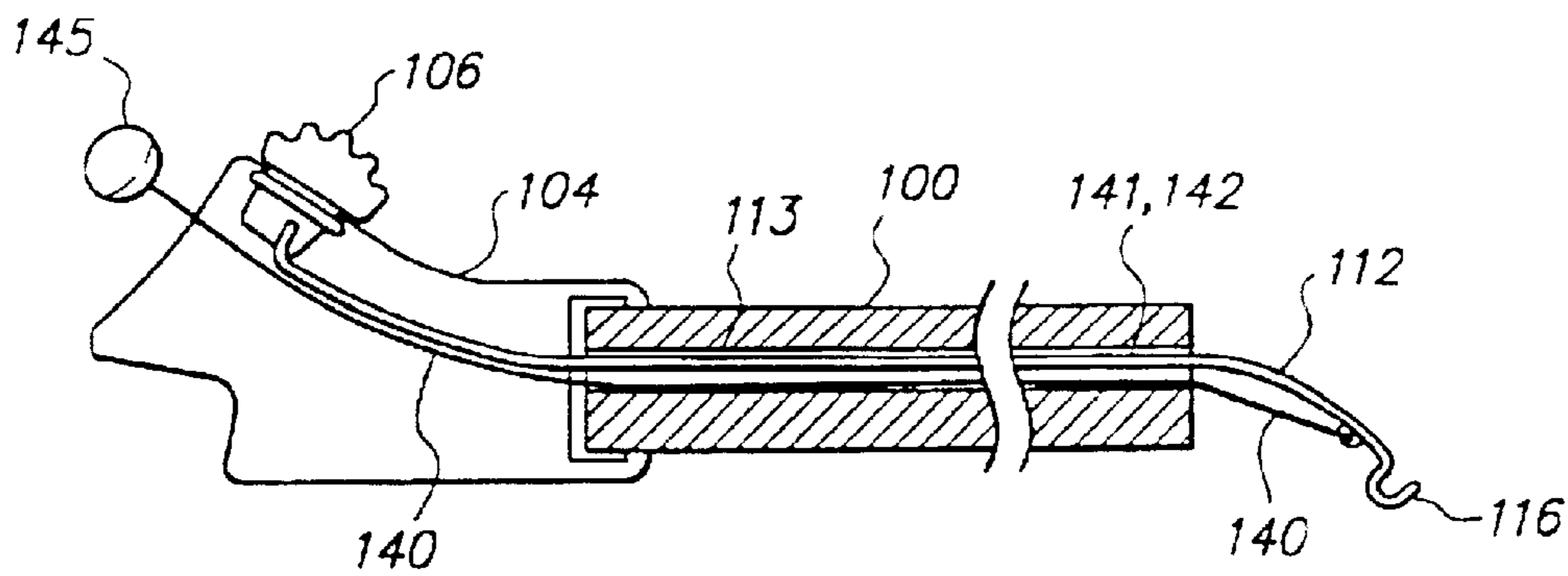


FIG. 6B

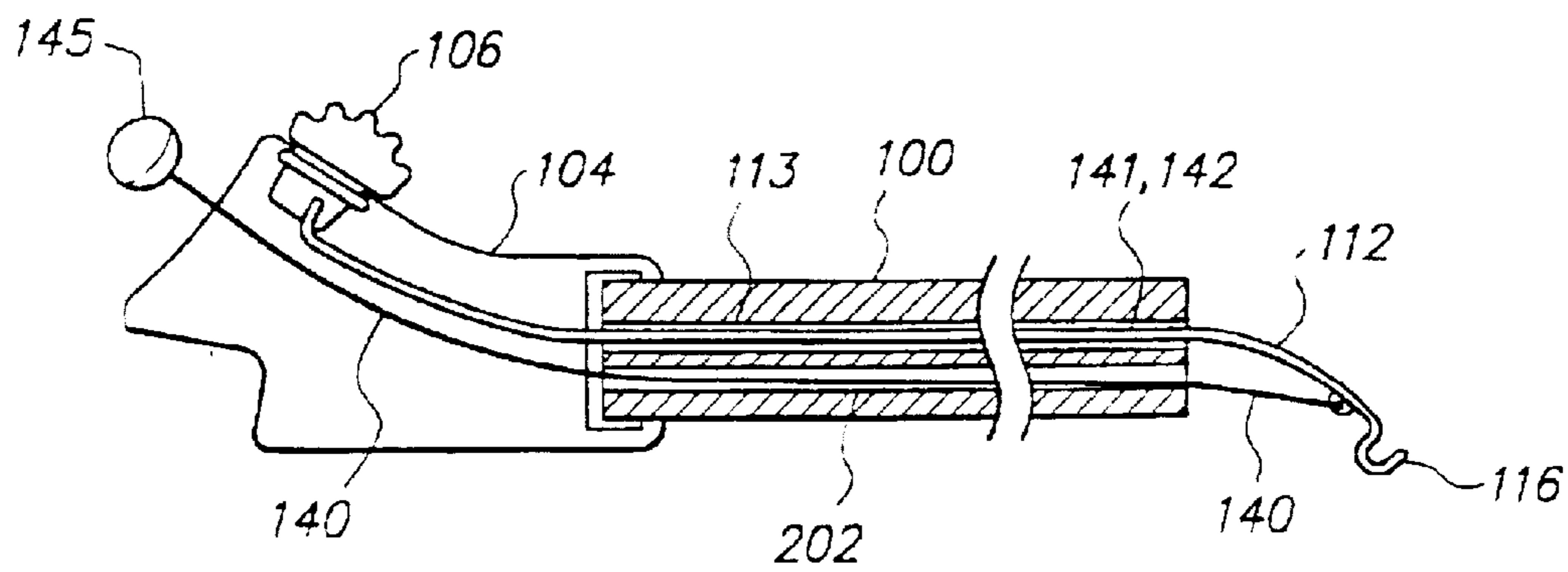


FIG. 6C

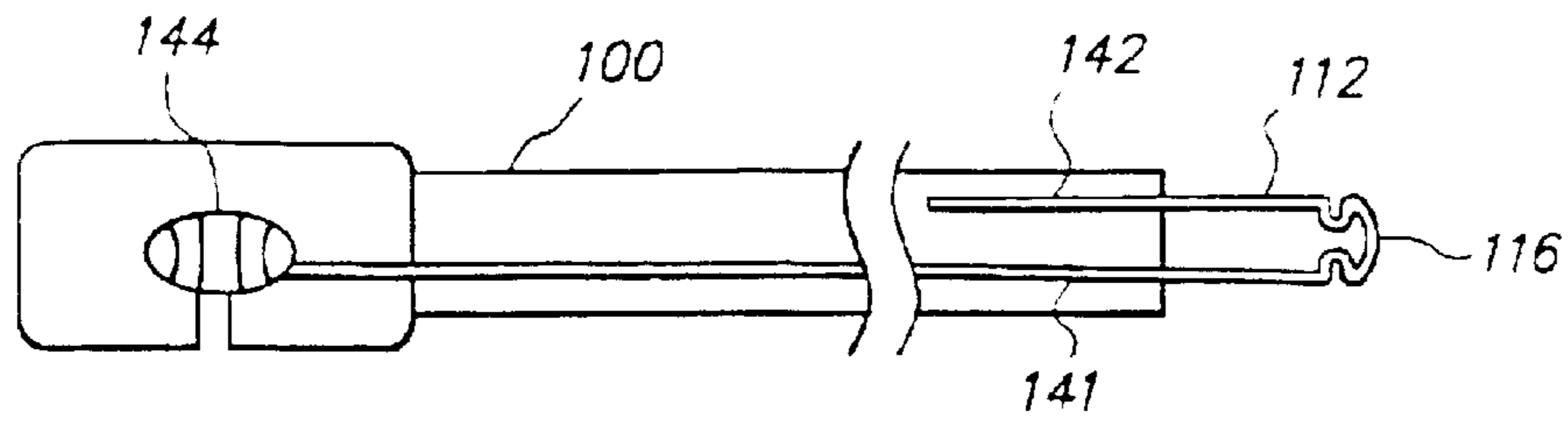


FIG. 7A

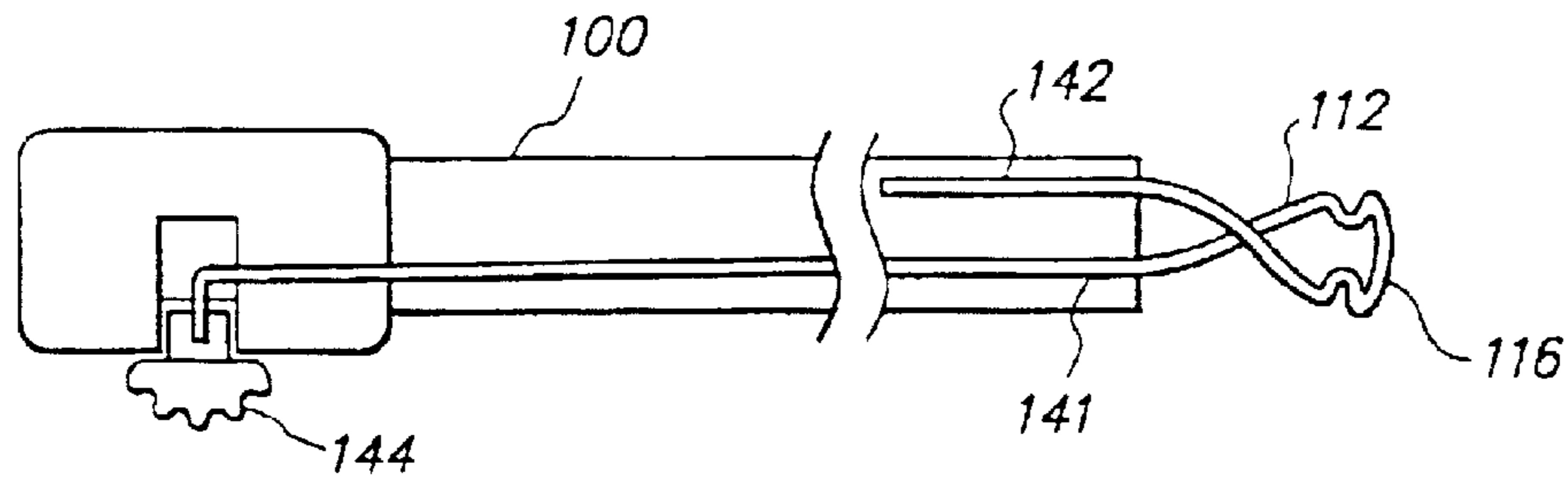


FIG. 7C

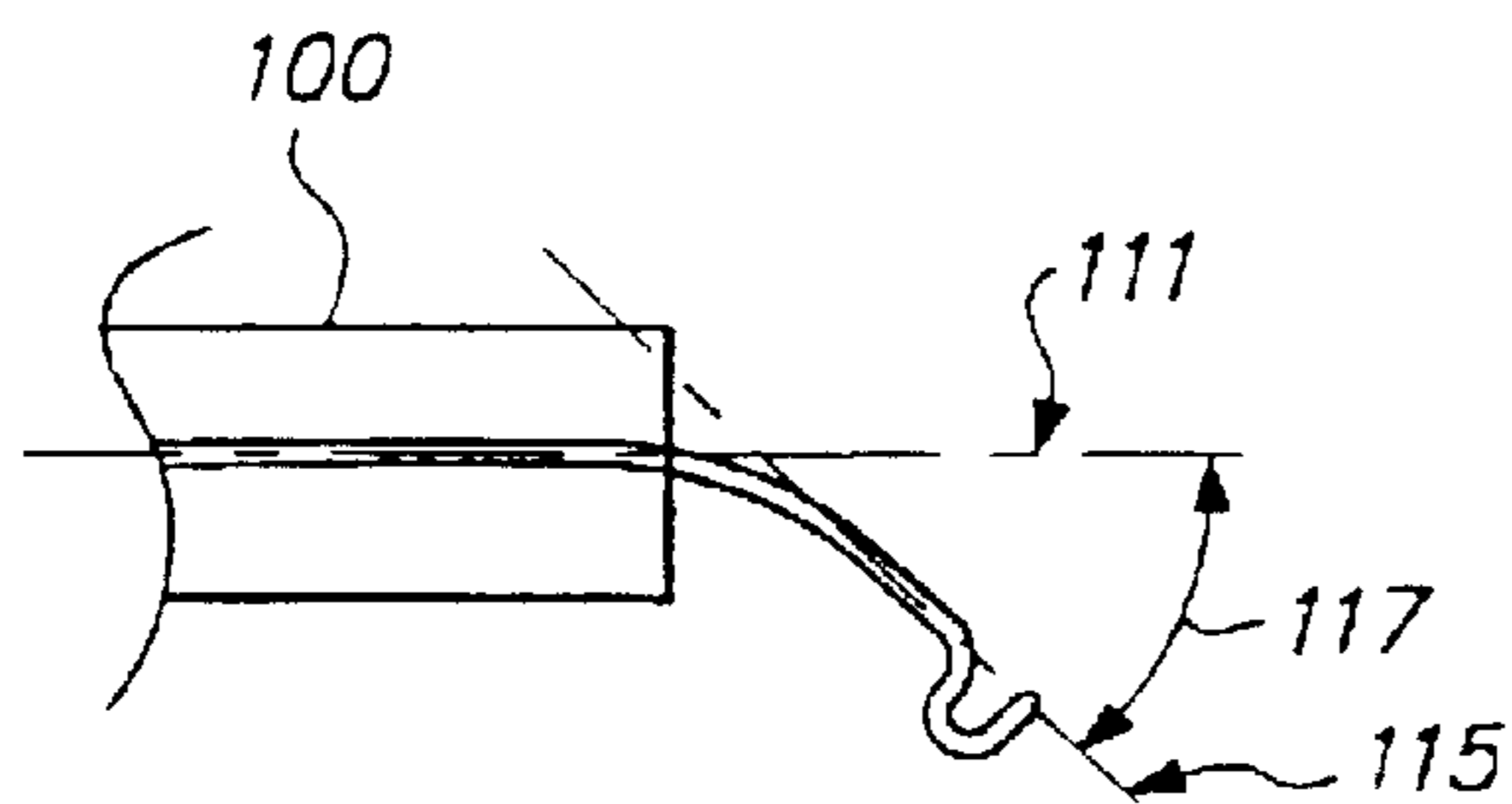


FIG. 7B

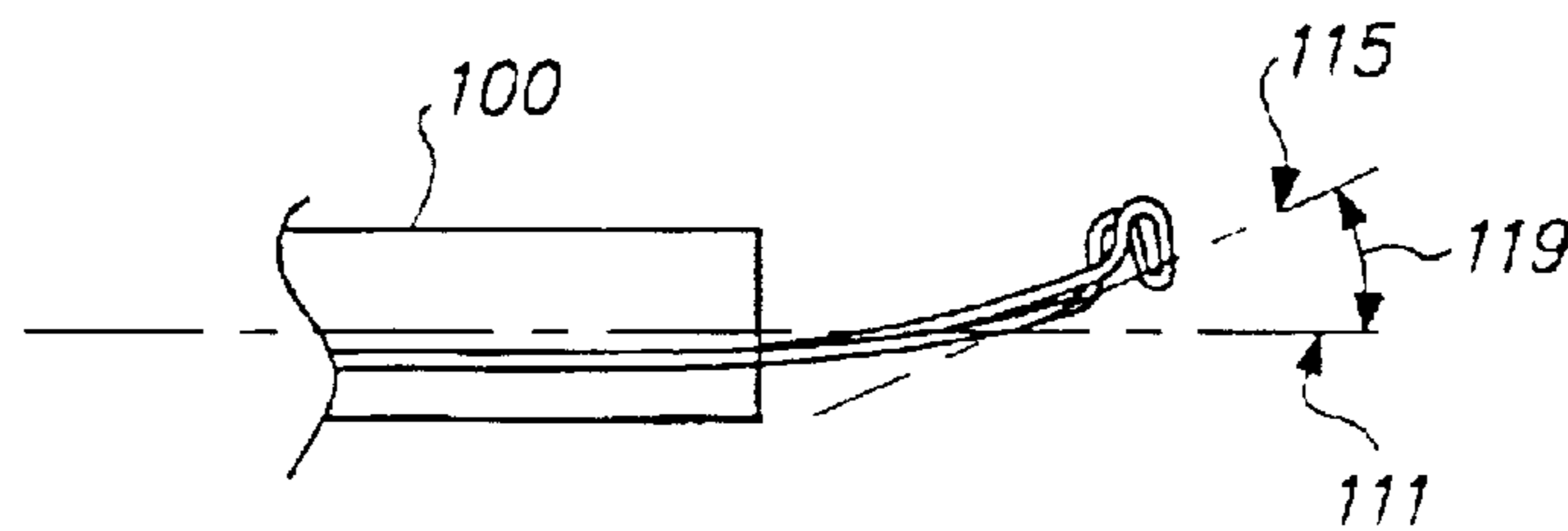


FIG. 7D

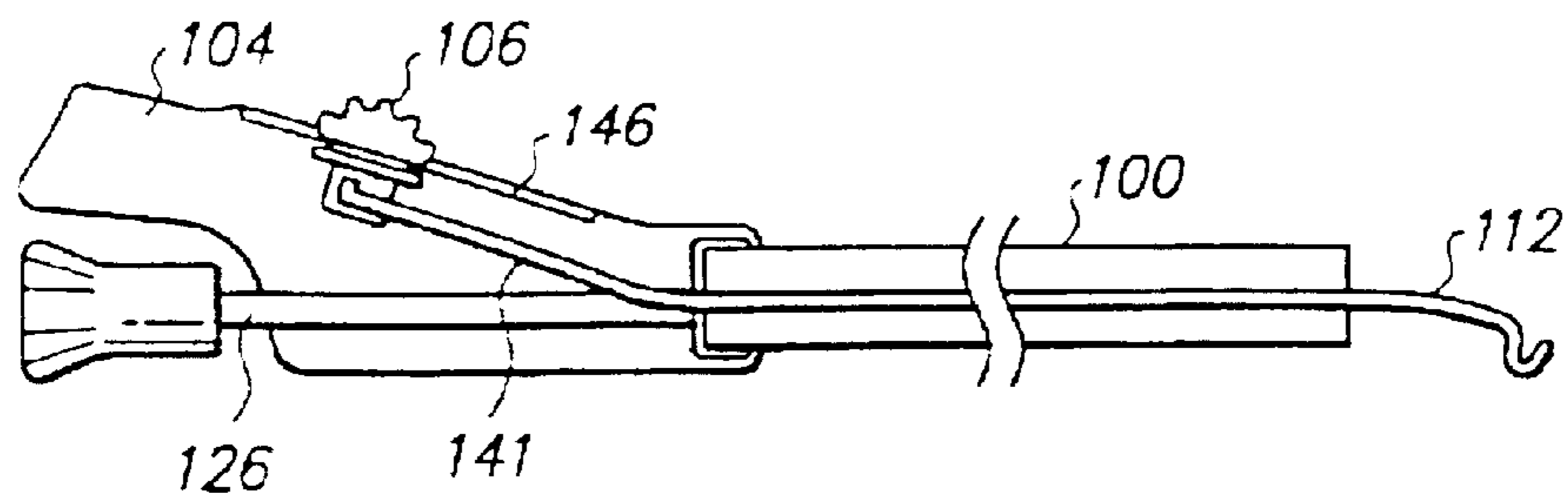


FIG. 8A

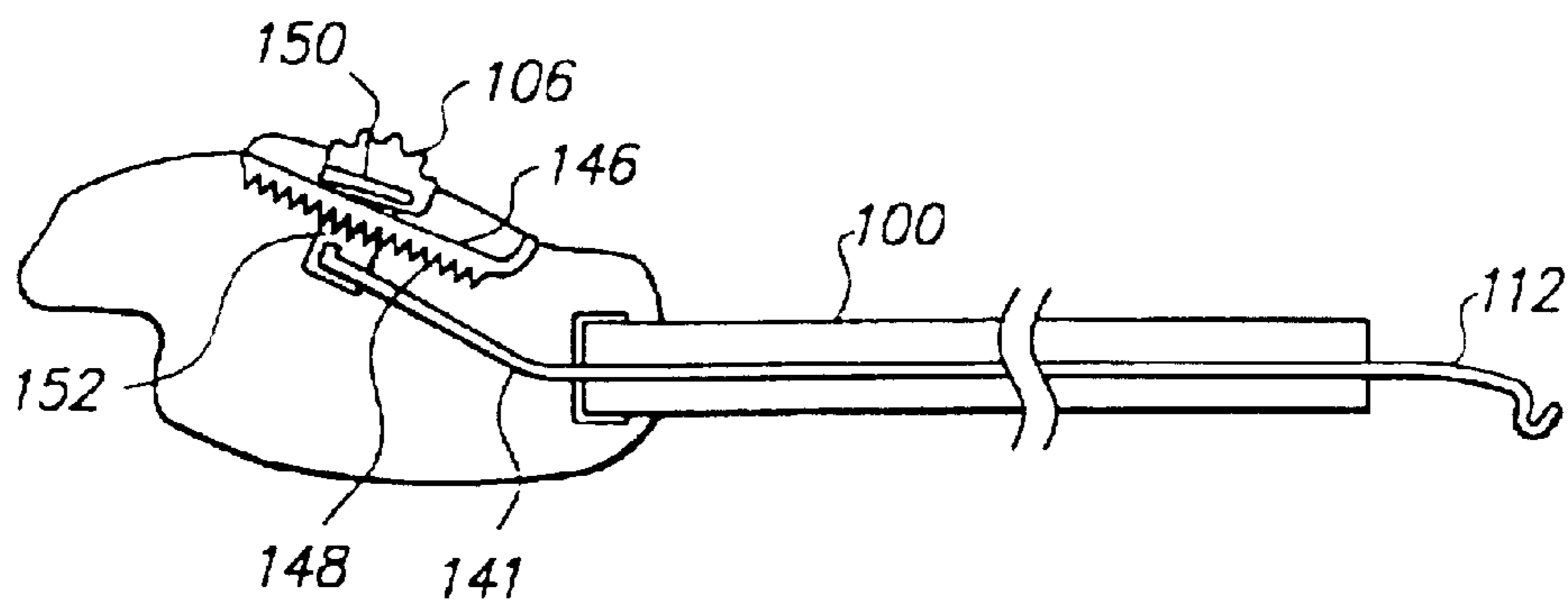


FIG. 8B

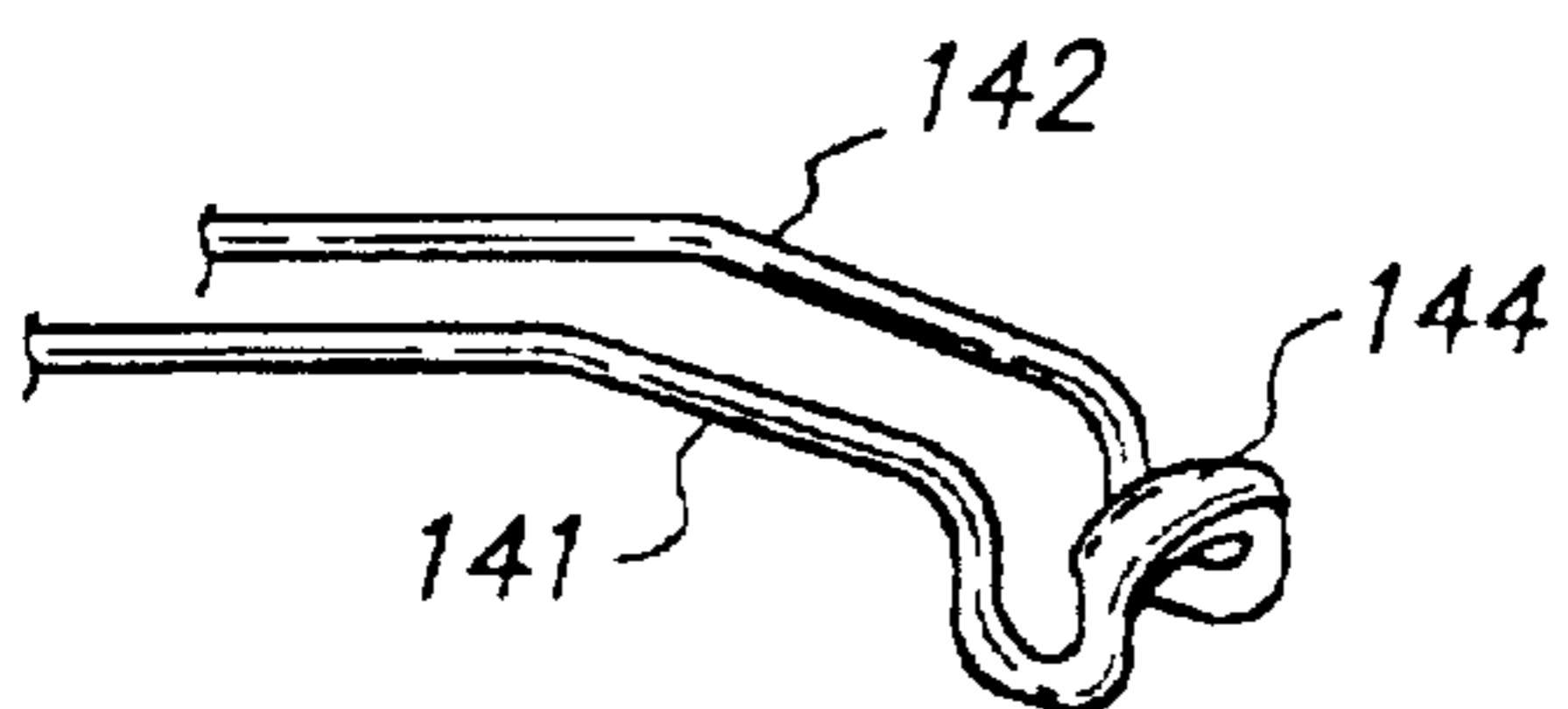


FIG. 9A

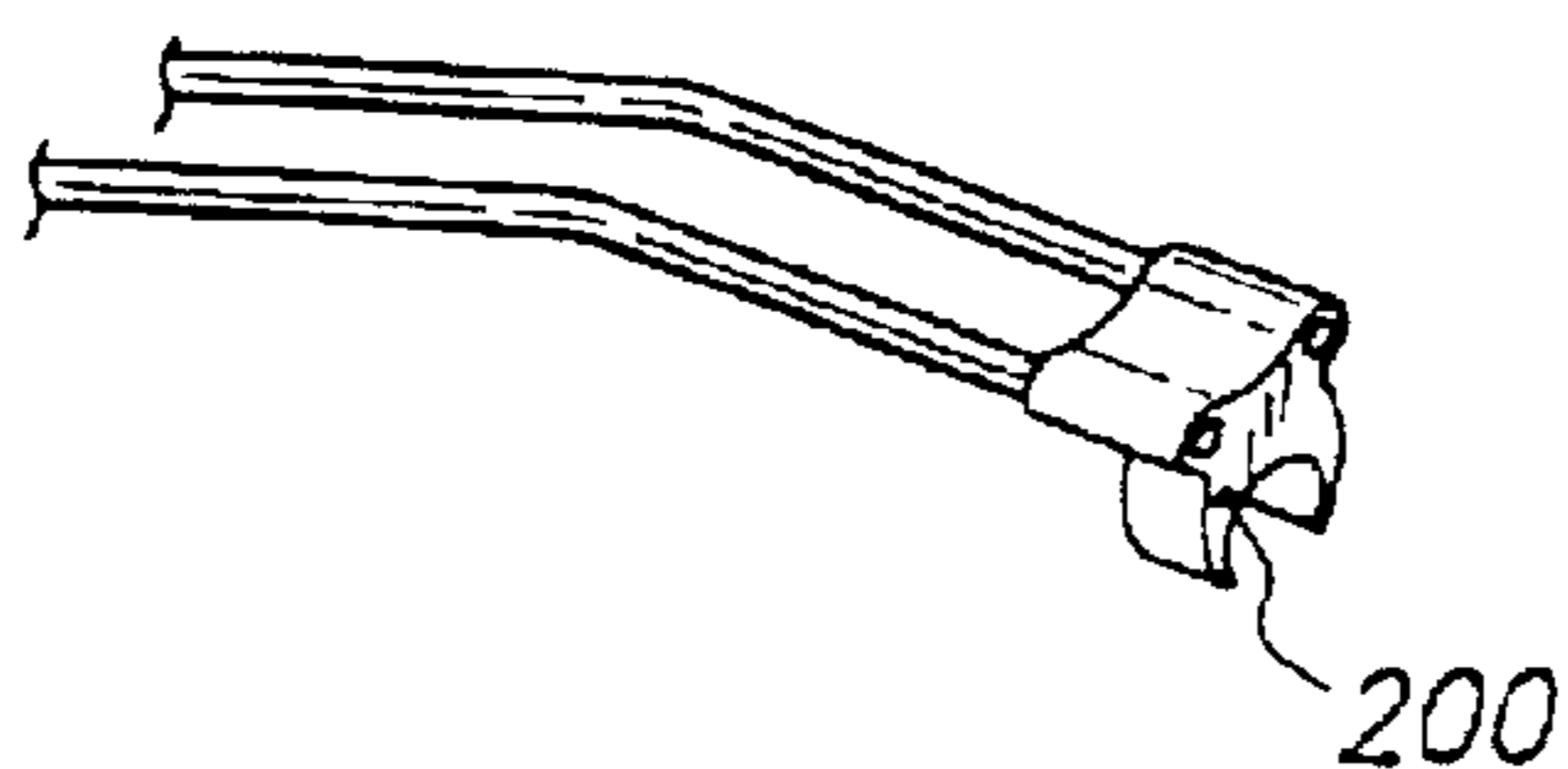
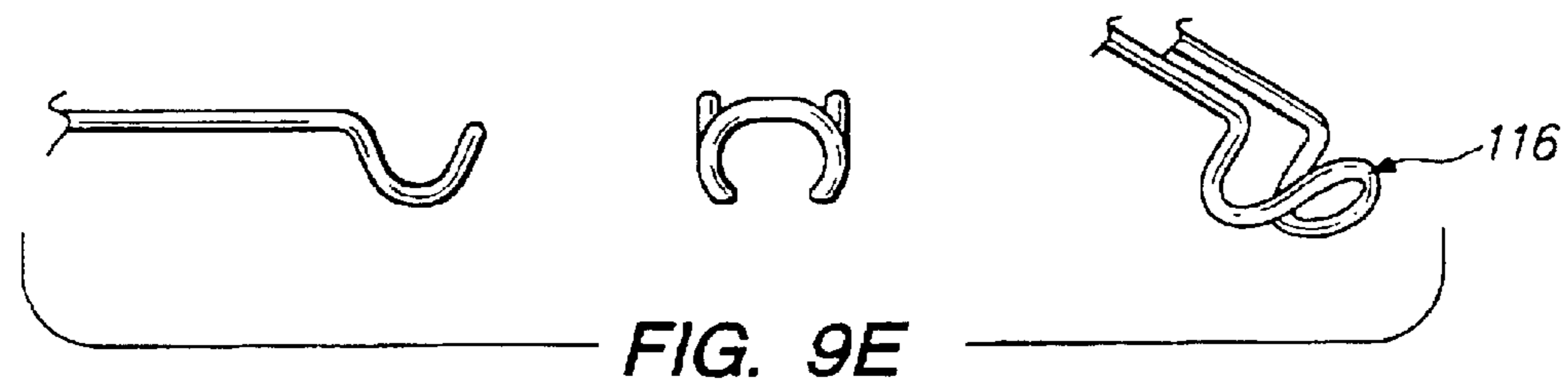
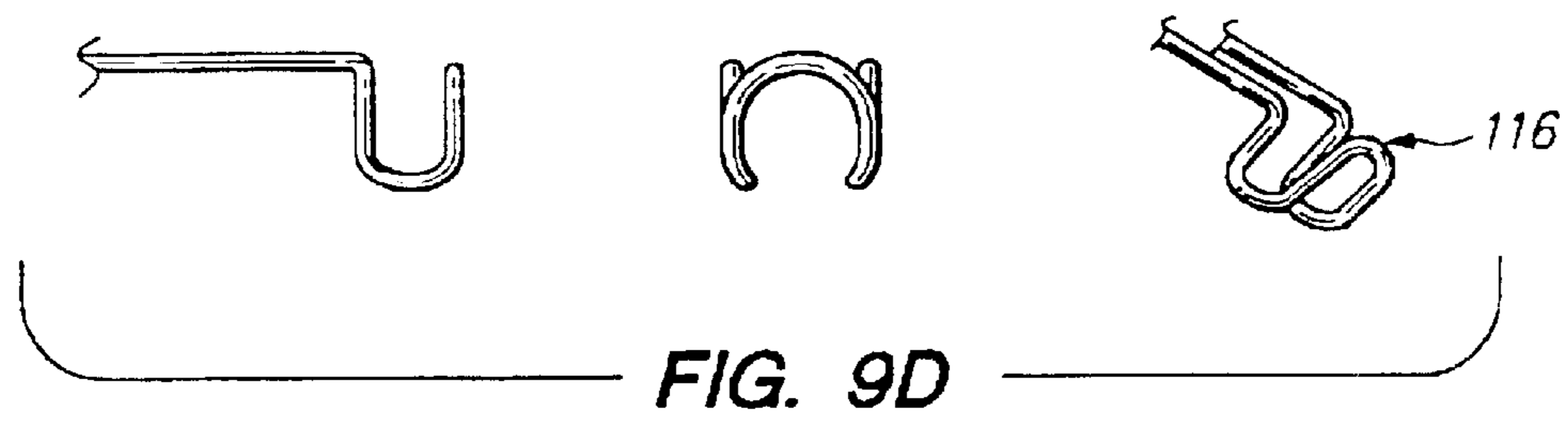


FIG. 9B



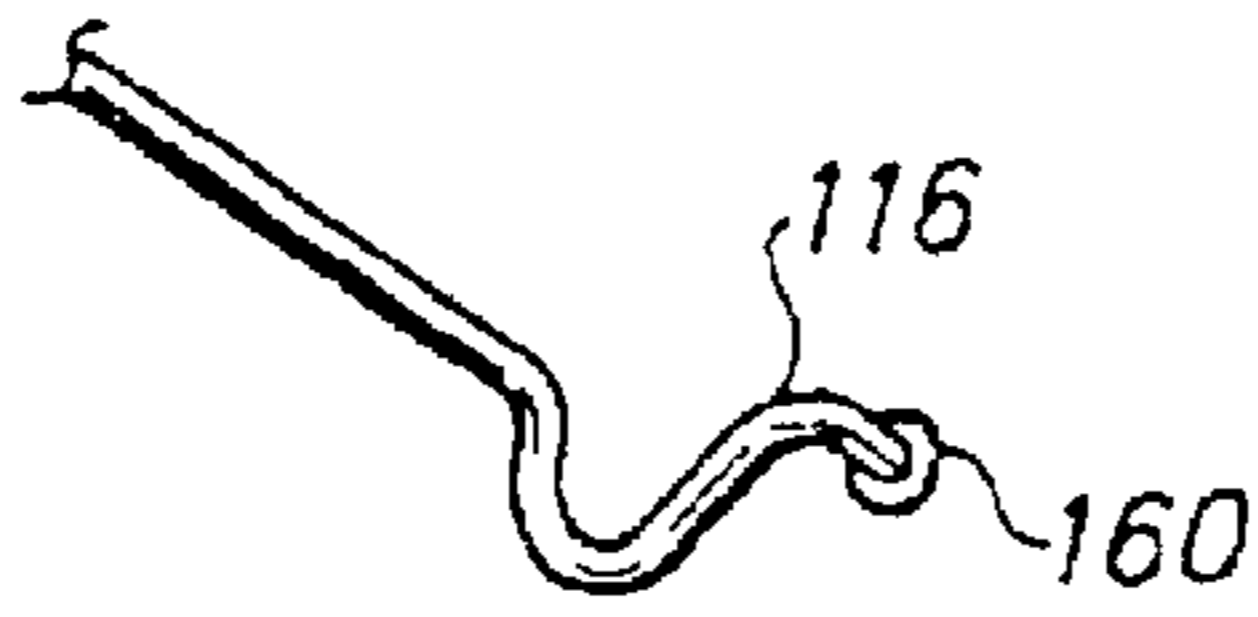


FIG. 9F

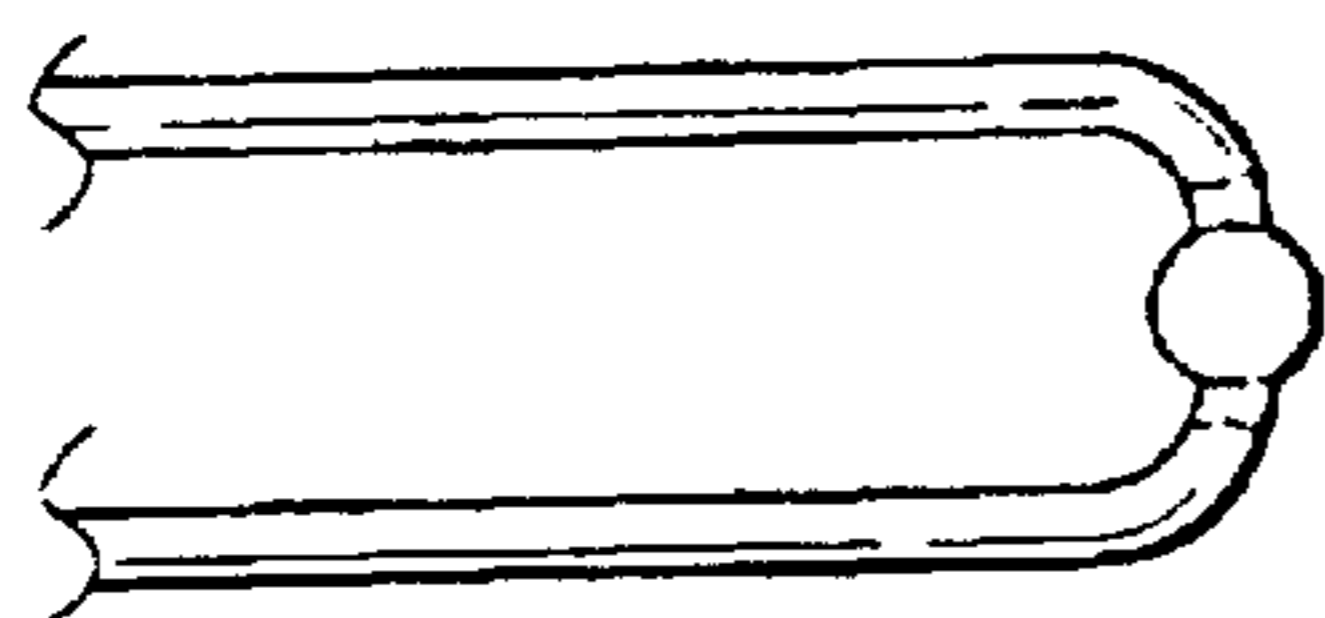
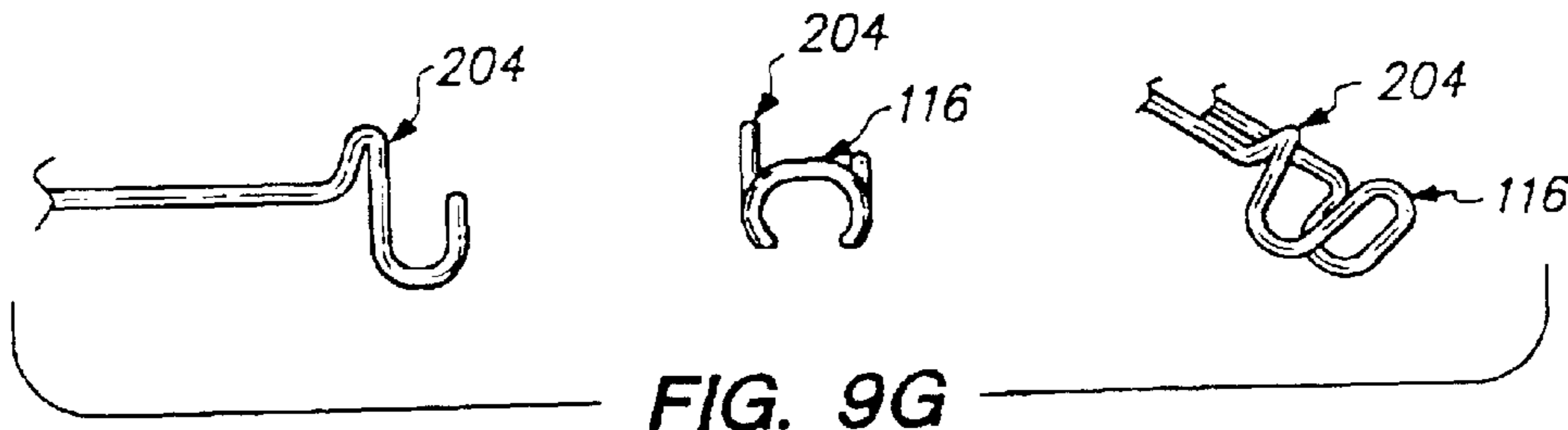


FIG. 10A



FIG. 10B

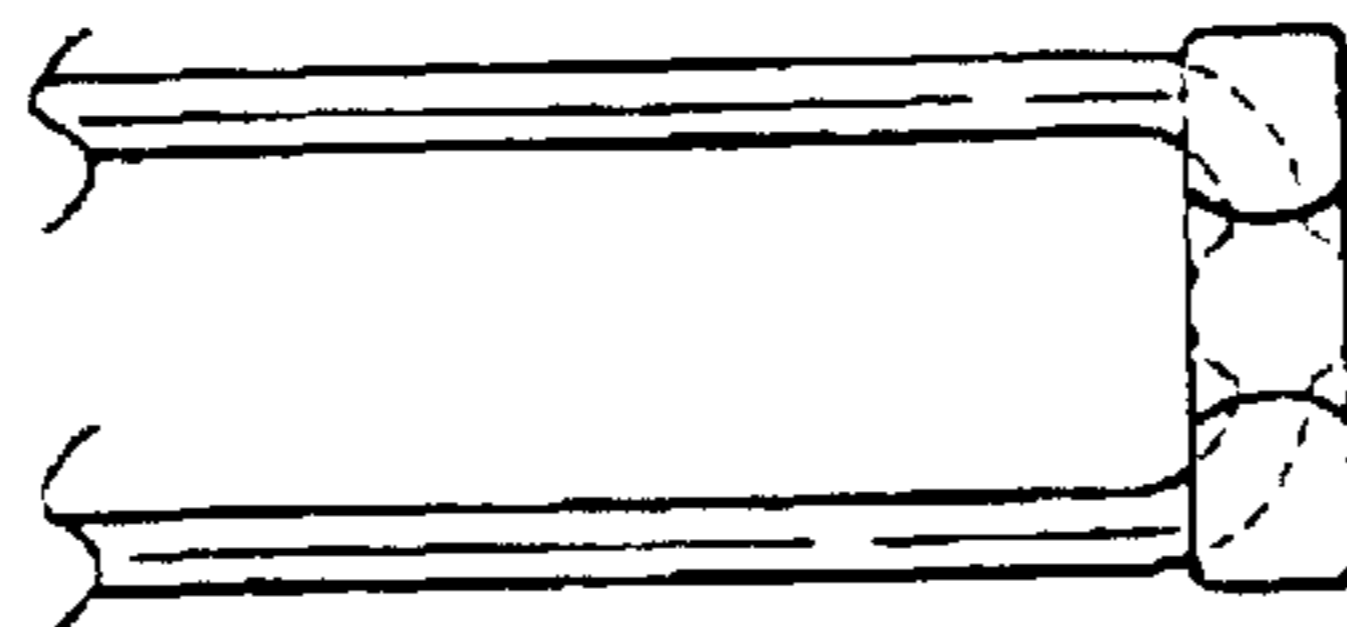


FIG. 10C

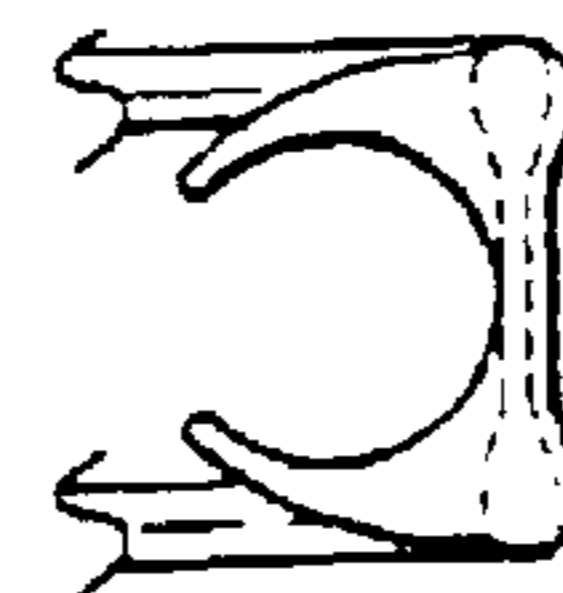


FIG. 10D

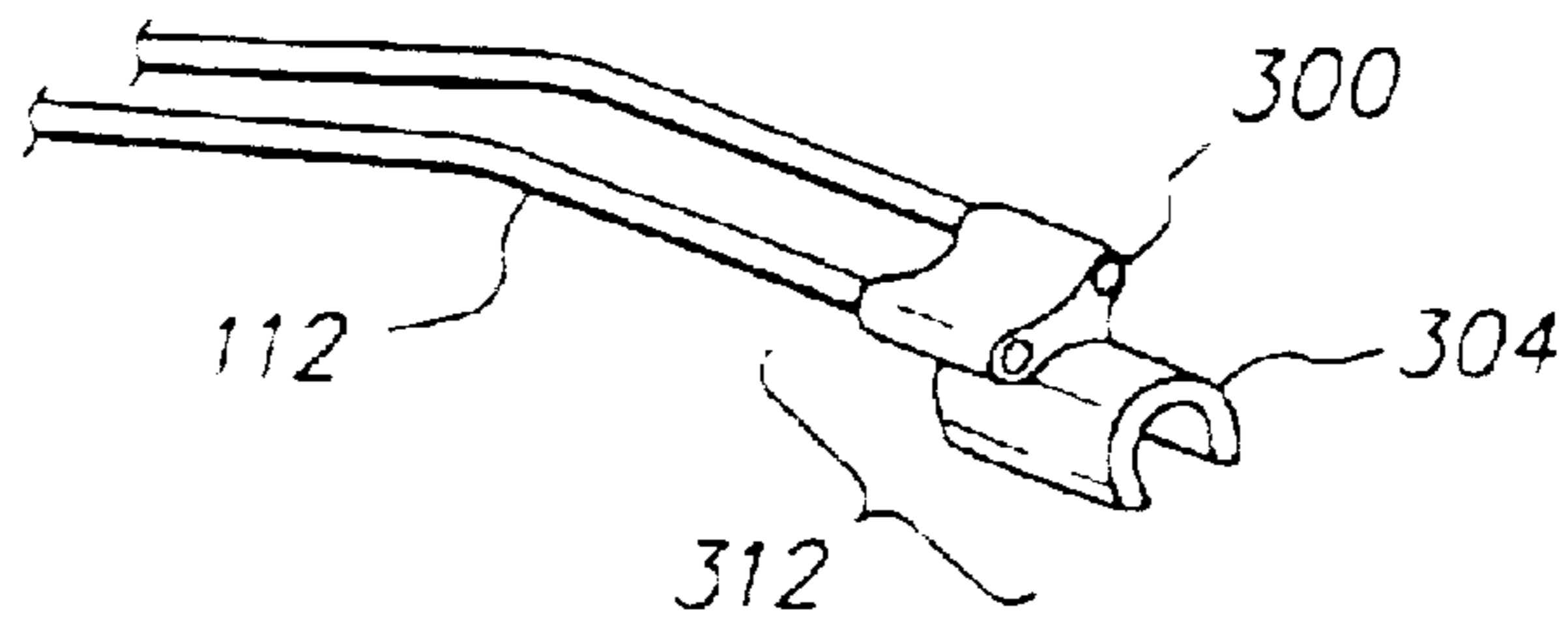


FIG. 11

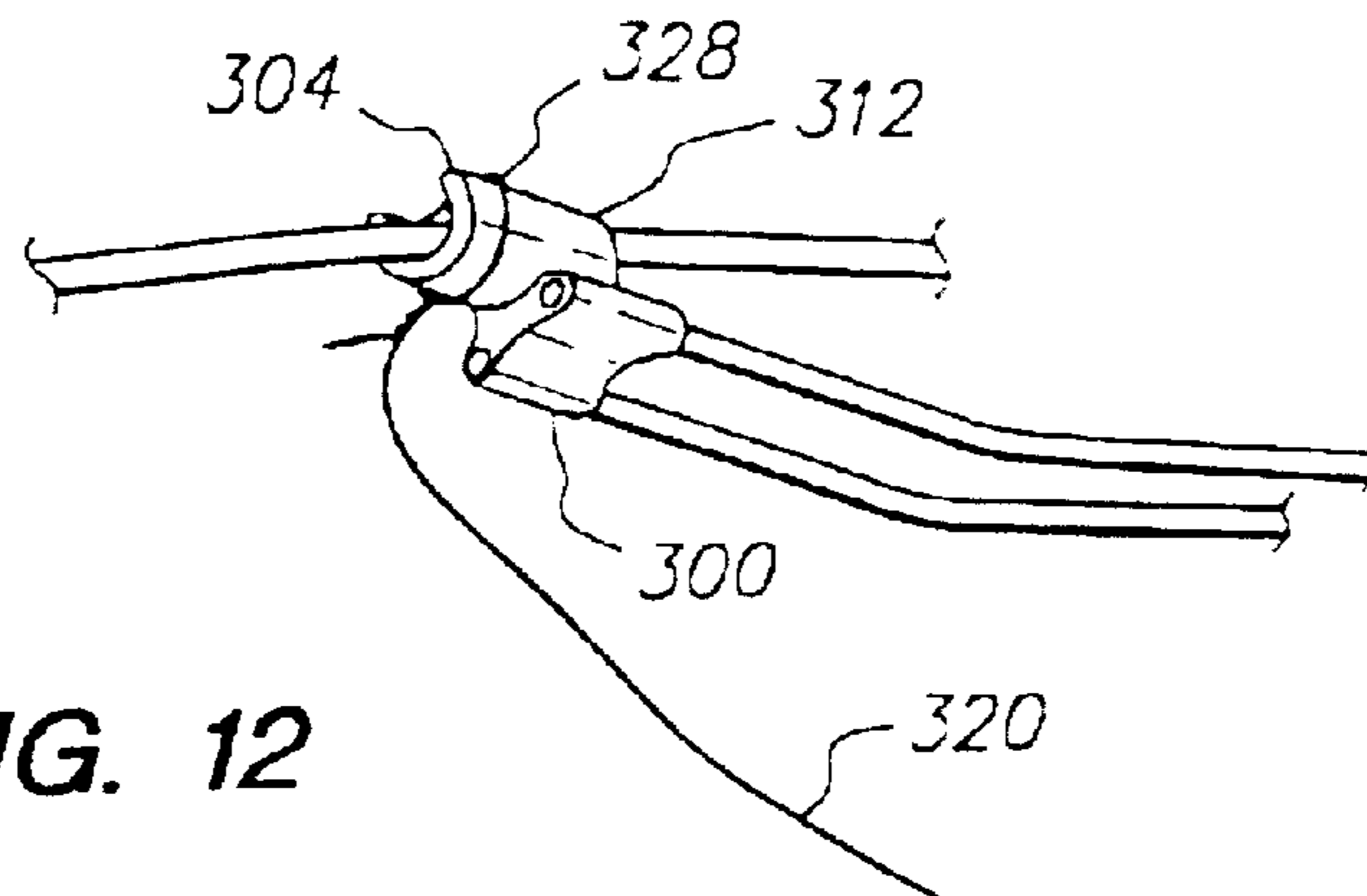


FIG. 12

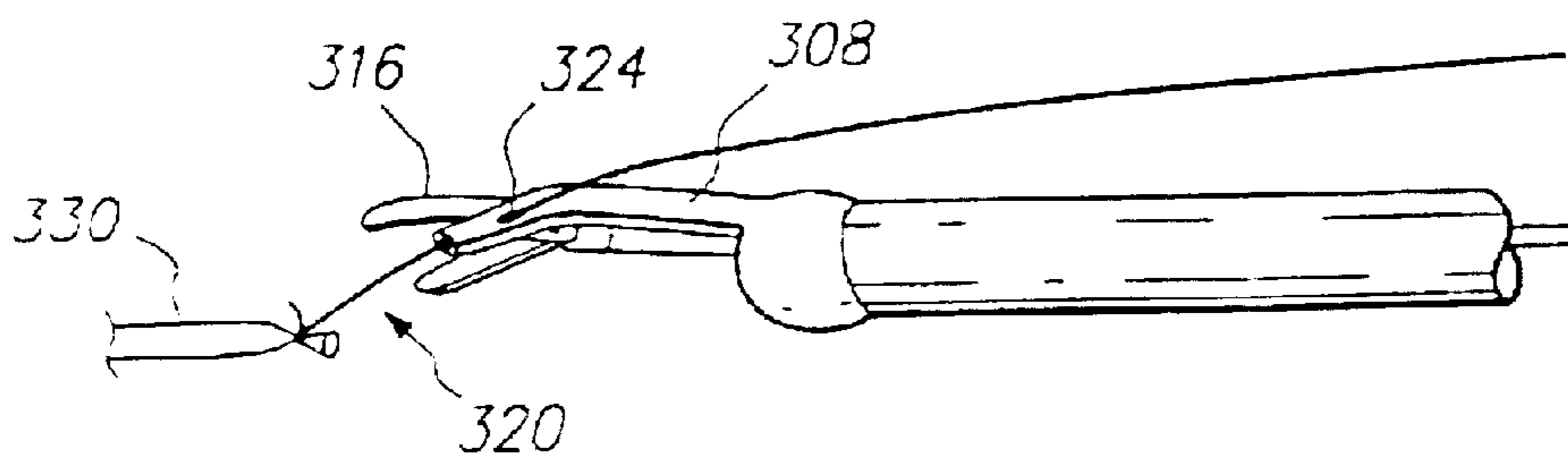


FIG. 15

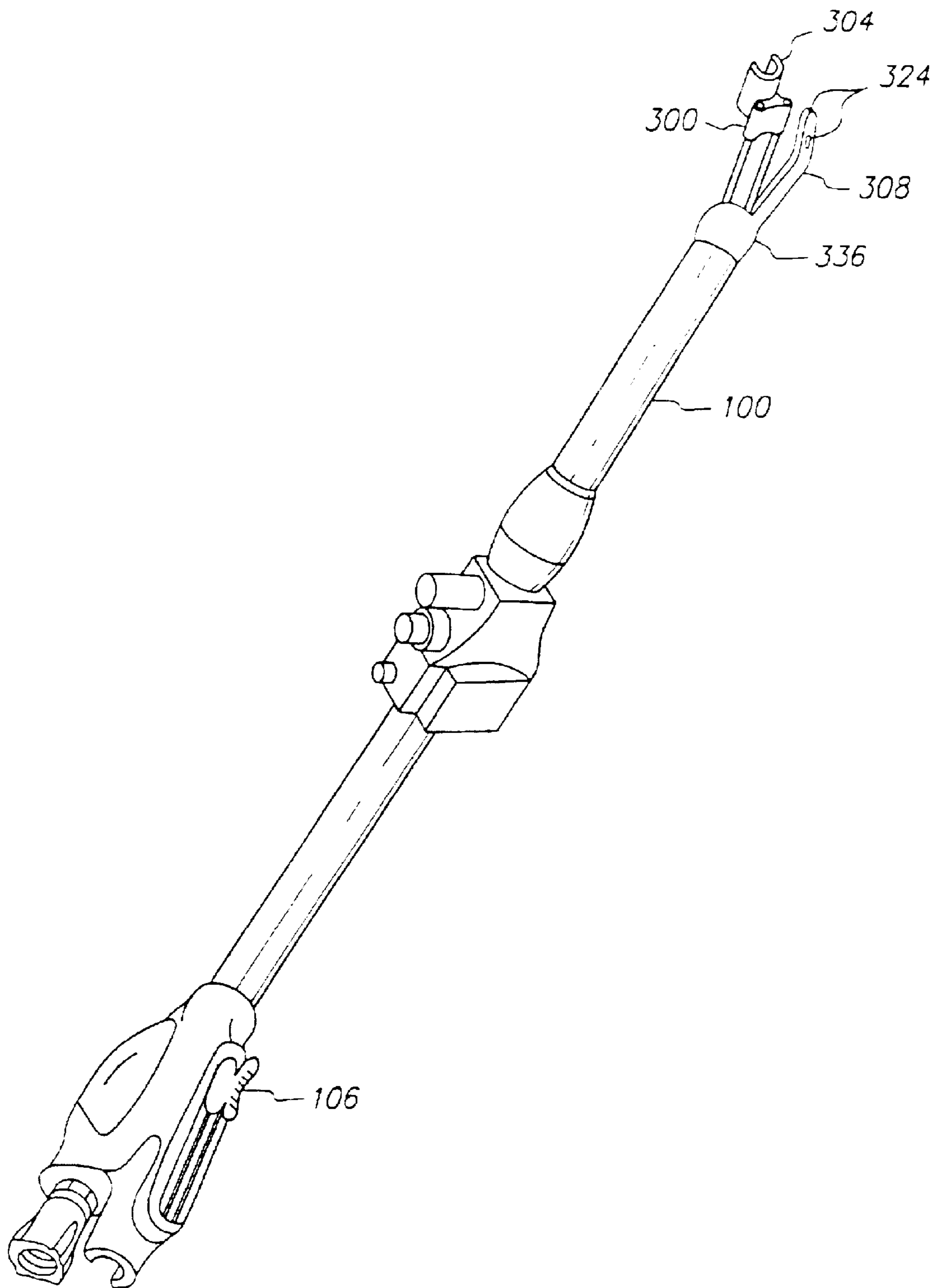
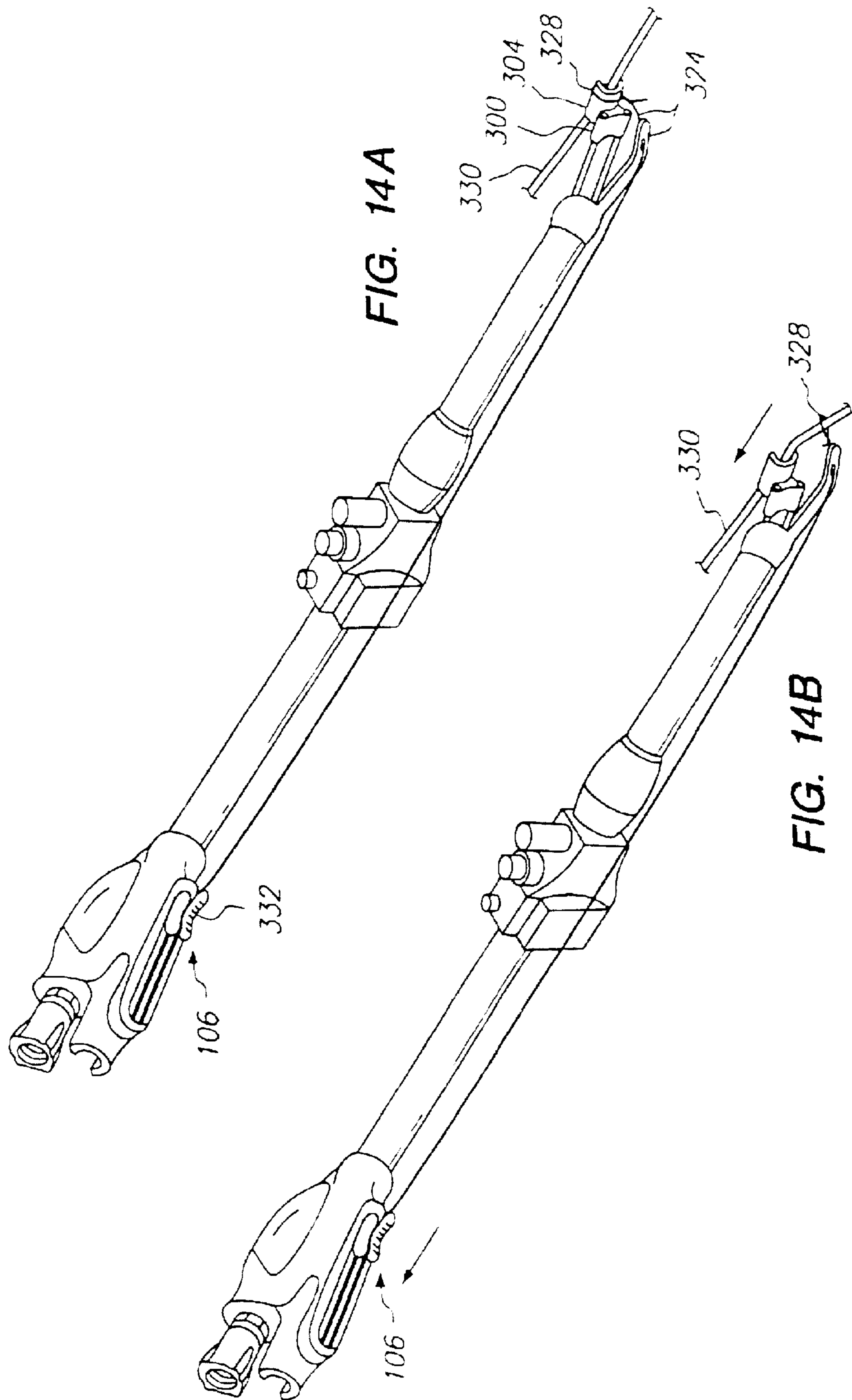


FIG. 13



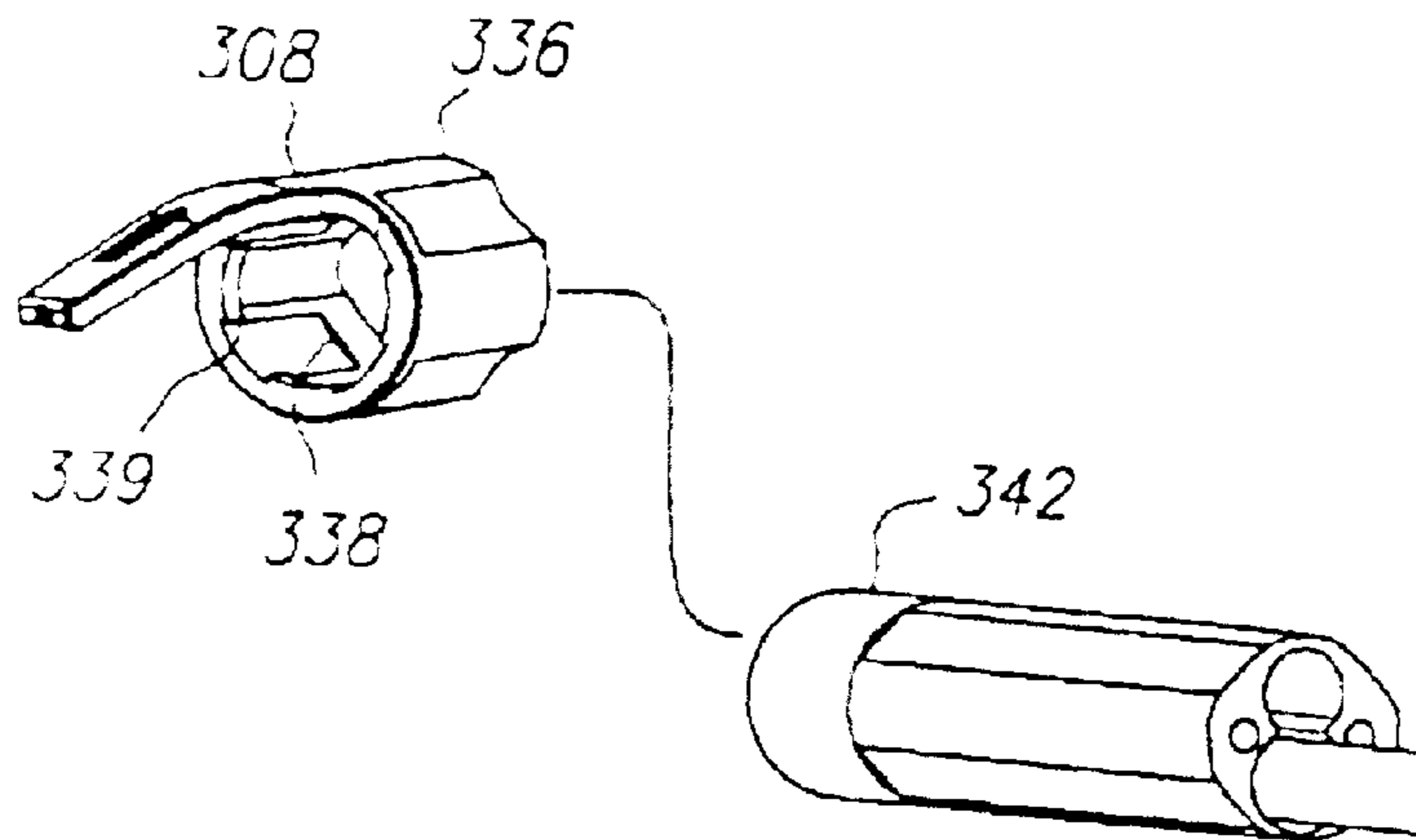


FIG. 16A

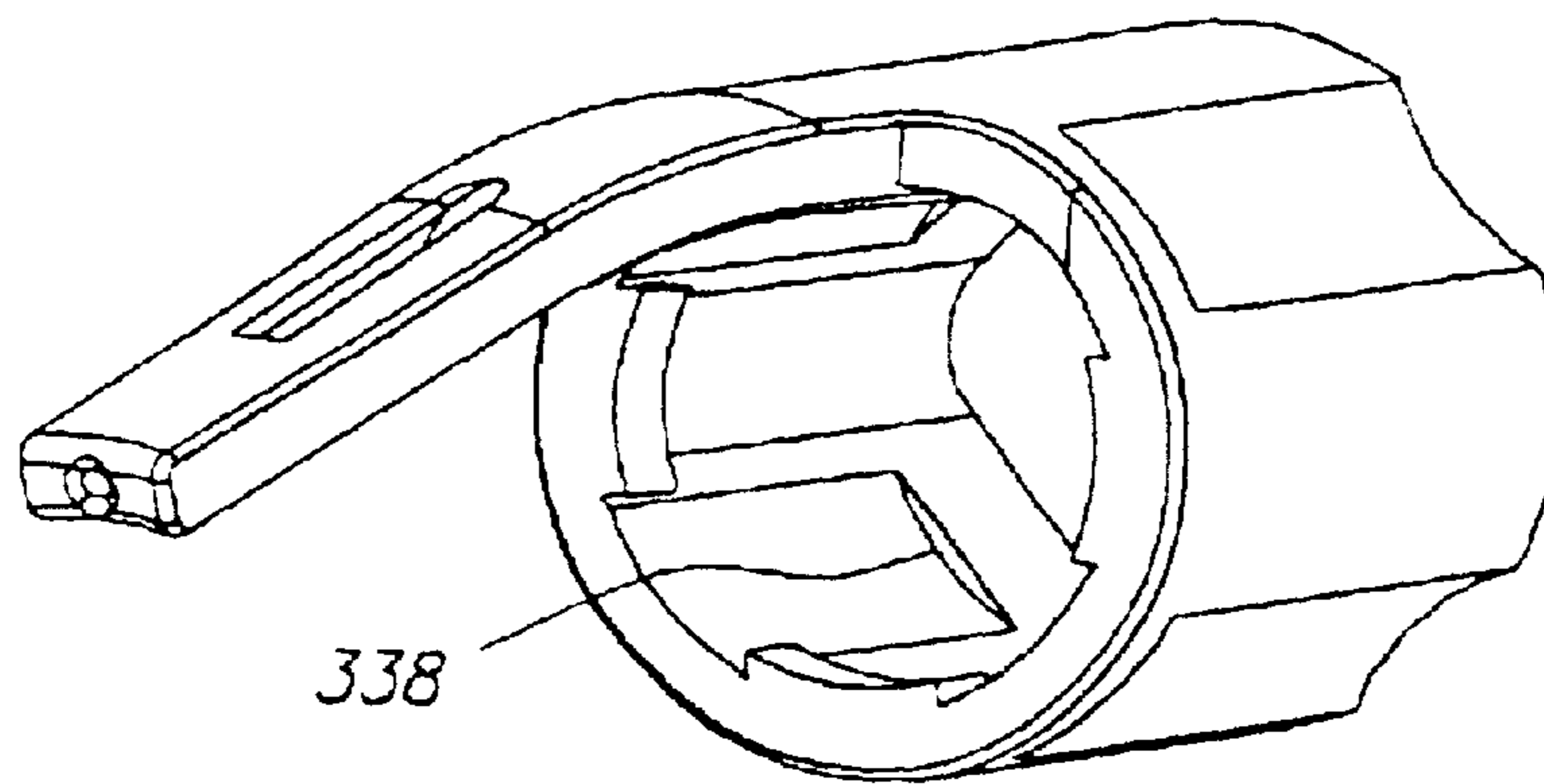


FIG. 16B

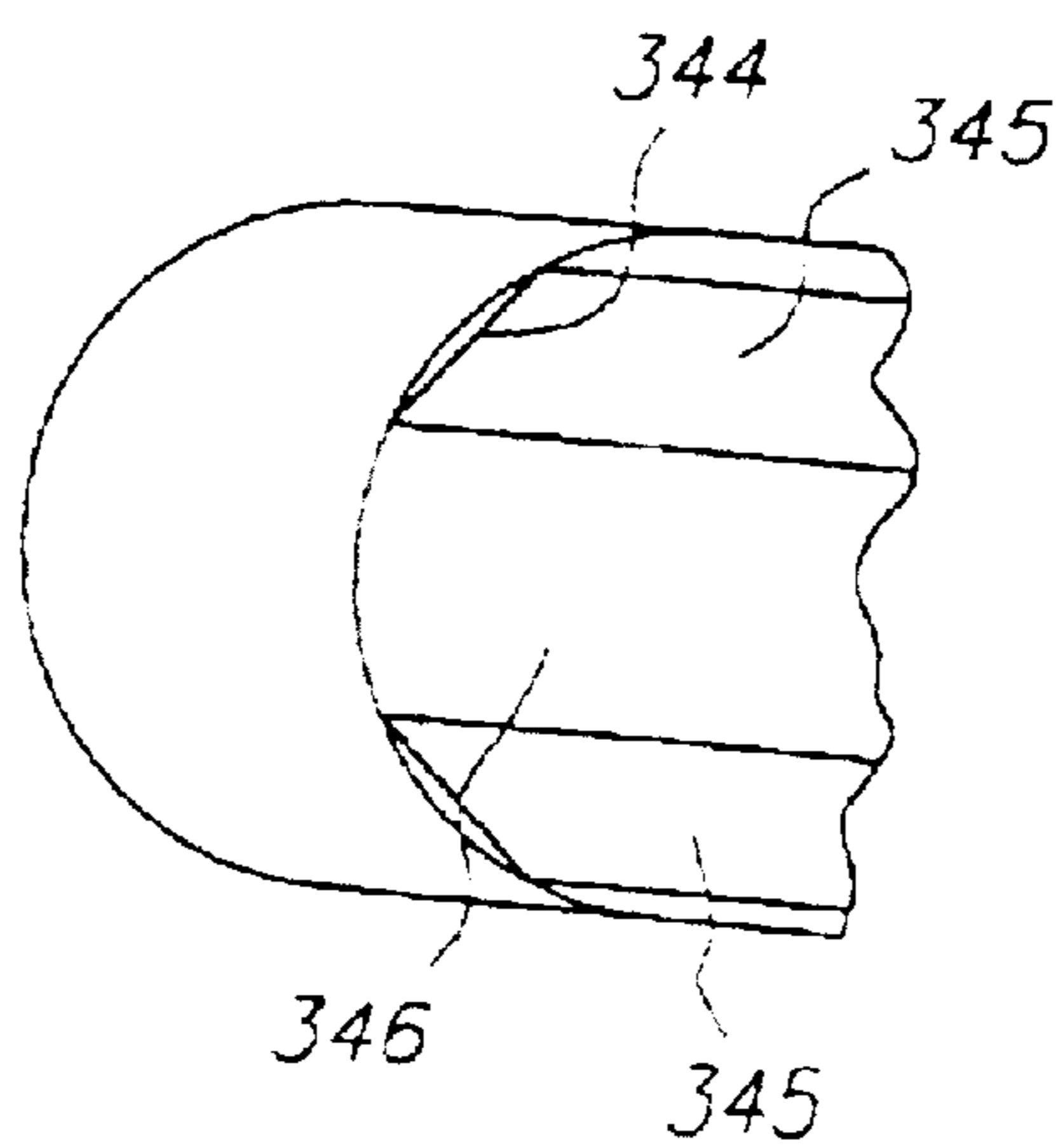


FIG. 16C

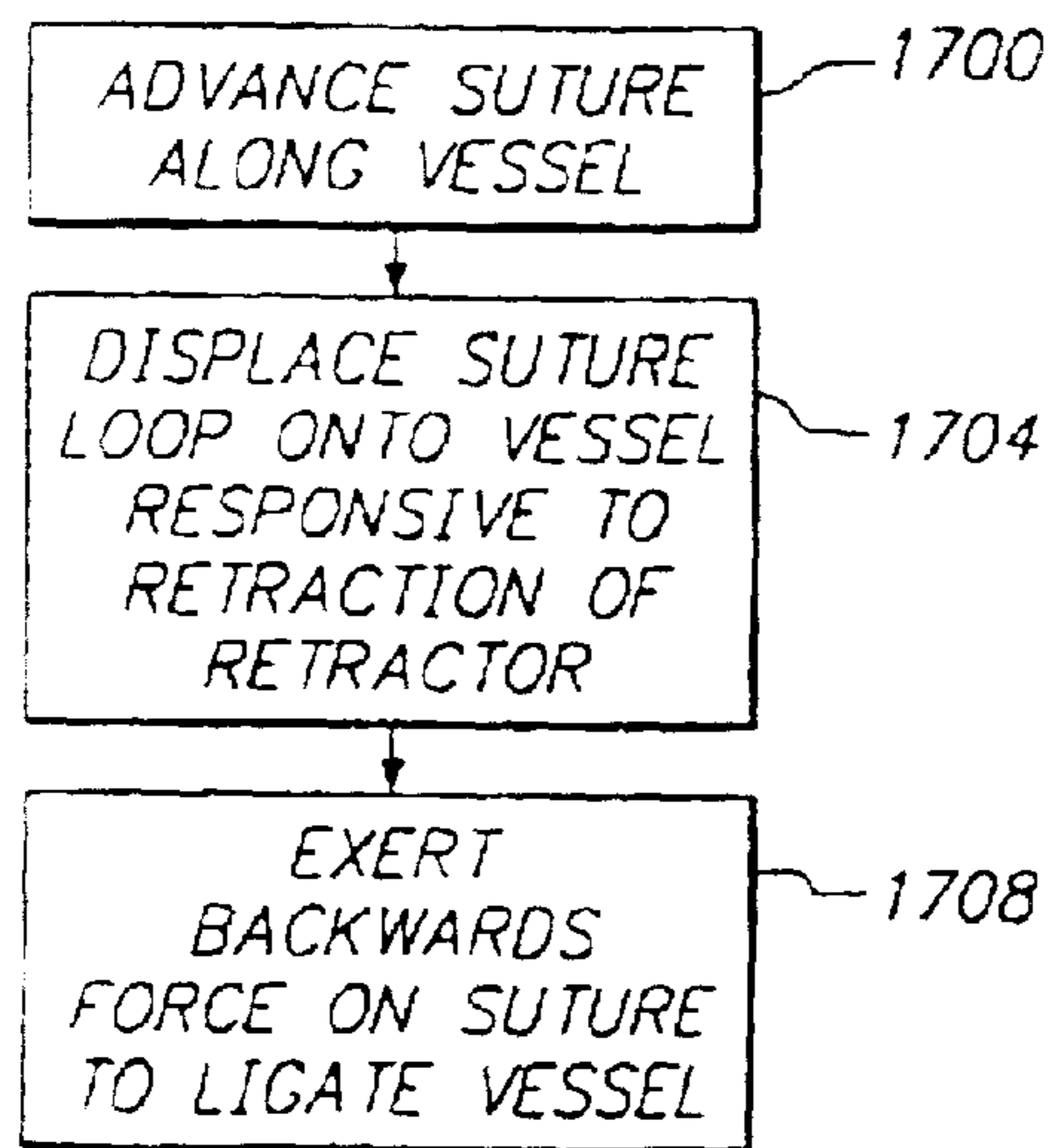


FIG. 17

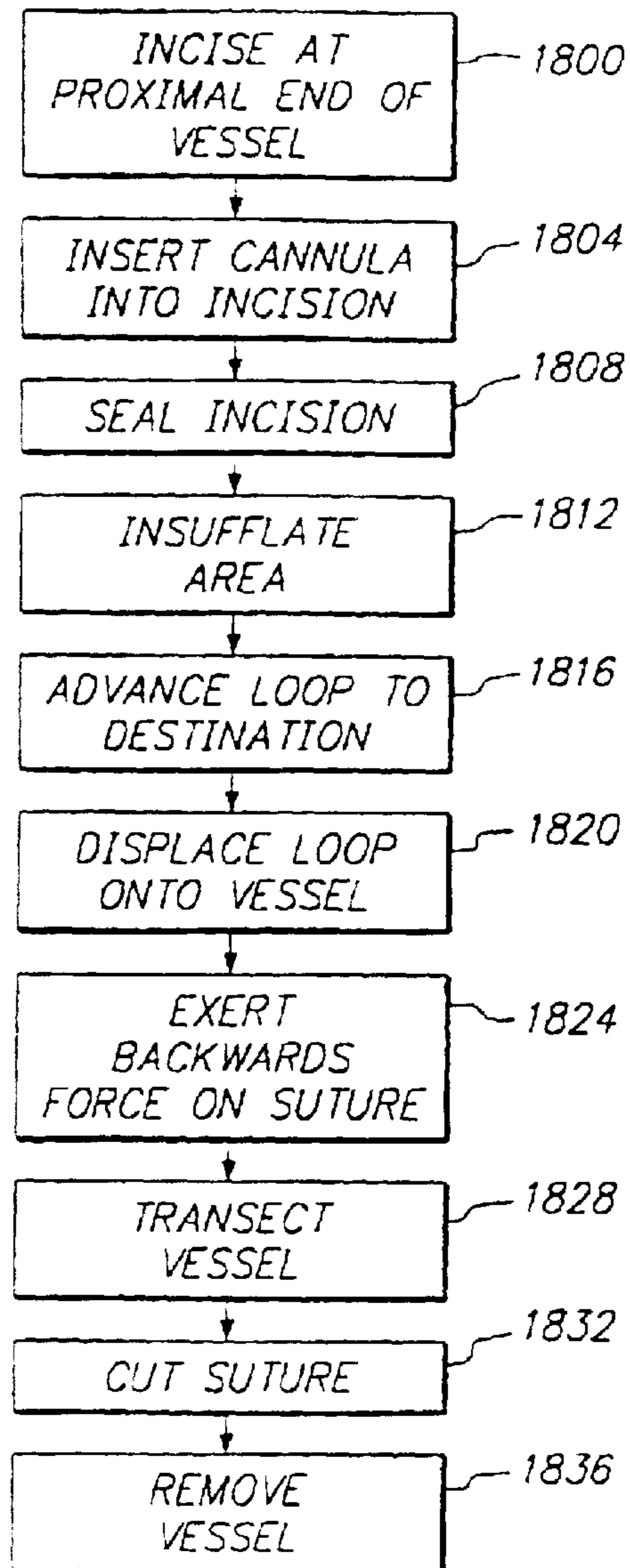


FIG. 18

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DEVICE AND METHOD FOR REMOTE VESSEL LIGATION

CROSS REFERENCE TO RELATED APPLICATIONS

The present application is a continuation of application Ser. No. 09/521,279 filed on Mar. 7, 200, now U.S. Pat. No. 6,348,037 which is a continuation of application Ser. No. 09/200,218 filed on Nov. 25, 1998, now U.S. Pat. No. 6,162,173, and a continuation-in-part application of application Ser. No. 09/102,723 filed on Jun. 22, 1998 now U.S. Pat. No. 5,895,353, which are incorporated herein in their entirety.

FIELD OF THE INVENTION

This invention relates to a cannula used for vessel retraction, and more particularly to a cannula and method that includes an endoscopic retractor for vessel ligation.

BACKGROUND OF THE INVENTION

Certain cannulas have surgical tools located within the cannula for performing surgical operations on a vessel of interest. The cannula is inserted into a surgical site with the distal end of the cannula positioned near the vessel of interest. An endoscope positioned within the cannula allows the surgeon to view the target area, and allows the surgeon to position the surgical tool correctly. One common procedure is to ligate a vessel or other tissue by tightening a suture loop tied as a slipknot on the vessel before transection to provide hemostasis to the vessel.

However, surgeons encounter several difficulties in ligation procedures. In one ligation procedure, a second incision must be made at the opposite end of the vessel of interest to ligate and transect the vessel. Multiple incisions are invasive and should be minimized if possible. In order to avoid this second incision, some conventional methods require tying a suture loop around the vessel, and pushing the loop along the vessel with a knot pusher until the opposite end is reached. Then, the loop is tightened to provide ligation. However, this procedure is difficult because the slipknot often catches on stumps of cut tributaries or other tissue, and then constricts around the vessel at the wrong position. Also, there is no easy method for transecting the vessel after the suture loop is tied to the vessel without potentially prematurely severing the suture.

Thus, a device and method is needed to allow remote, one-incision, ligation of a vessel which allows a suture loop to be moved reliably to the site of interest, and ensures that the transection instrument is able to transect the vessel, and cut the suture.

SUMMARY OF THE INVENTION

In accordance with the present invention, a retractor is positioned within a cannula with a dissection cradle end of the retractor positioned at the distal end of the cannula. The retractor includes a first portion that has an axis approximately parallel to a central axis of the cannula, and a second portion that has an axis which is at an angle with respect to the central axis of the cannula. The dissection cradle is located at the distal end of the second portion of the retractor. In another embodiment, the retractor includes two legs having substantially parallel axes that selectively protrude from the distal end of the cannula. The protruding legs support the dissection cradle formed in the shape of a loop that is positioned in a plane skewed relative to the axes of the

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legs, with a bottom of the loop directed away from the cannula. Thus, in operation, when the surgeon locates a vein and side branch of interest, the surgeon extends the retractor to cradle the vein in the dissection cradle. Once cradled, the retractor may be fully extended, pulling the vein away from the axis of the cannula, causing the side branch to be isolated and exposed to a surgical tool. The surgical tool may then be extended from within the cannula to operate on the isolated and exposed side branch.

In another embodiment, the top of the loop of the dissection cradle is flat and thin, allowing atraumatic support of the vein, and minimizing contact between the retractor and the surgical tool. In yet a further embodiment, the retractor includes a single leg with the loop formed by the one leg of the retractor, and with a stopper coupled to the distal end of the retractor. In still another embodiment, the cannula comprises a sliding tube which encases the retractor, and in a first position is extended out to encase the second portion of the retractor, and in a second position is extended to encase only the first portion of the retractor. In response to being in the first position, the second and first portions of the retractor are both approximately parallel to the axis of the cannula. In the second position, the second portion of the retractor is skewed relative to the axis of the cannula.

In accordance with an alternate embodiment of the present invention, a retractor is positioned within a cannula with a dissection cradle end of the retractor positioned at the distal end of the cannula. The dissection cradle comprises a shoulder part and a curved channel part. Suture forming a suture loop is threaded through a hole in a tension mount that is fixed to the distal end of the cannula and is abutted against the distal end of the shoulder. Upon advancement to the surgical site of interest, the suture loop is safely maintained in place due to the tension provided by the tension mount and the support provided by the shoulder. The curved channel provides a groove in which the vessel of interest may be cradled. Upon retraction of the retractor, the suture loop is displaced onto the vessel at the desired position for ligation. In one embodiment, the loop is tightened by detaching the proximal end of the suture from the cannula and pulling on the suture, constricting the suture loop. In an alternate embodiment, a manual controller for retracting the retractor is attached to the proximal end of the suture. Upon slidable retraction of the manual controller, the retractor is retracted, the loop is displaced onto the vessel, and the loop is tightened.

In a further embodiment, a transecting device is positioned within the cannula. The distal end of the tension mount is positioned to allow the distal end to be proximal to the shoulder of the dissection cradle responsive to the shoulder being in an axial position relative to the tension mount. This results in the suture and vessel being reliably positioned within reach of the transecting device for transection of the vessel and cutting of the suture.

Finally, in a preferred embodiment, the retractor has a distal end having an axis skewed relative to the central axis of the cannula, thus facilitating accurate positioning of the vessel and suture for transection and cutting, and ensuring the proper displacement of the suture loop onto the vessel in response to the retraction of the retractor.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a preferred embodiment of cannula **100** showing retractor **112** in an extended position.

FIG. 2a is a cut-away side view of retractor **112** and cannula **100**.

FIG. 2b is a top view of retractor 112.

FIG. 3a is a perspective side view of cannula 100 with a saphenous vein positioned within the cradle 116.

FIG. 3b is a perspective side view of the distal end 122 of cannula 100 in an embodiment in which an endoscope 126 and a surgical tool 120 are present and partially extended.

FIG. 3c is a front view of the distal end 122 of cannula 100 in which the surgical tool 120 and the retractor 116 are partially extended, and an endoscope 126 is present.

FIG. 4a is a cut-away top view of cannula 100.

FIG. 4b is a cut-away side view of cannula 100.

FIG. 5a is a cut-away view of a sliding tube embodiment of cannula 100 in a first position.

FIG. 5b is a cut-away view of the sliding tube embodiment of FIG. 5a in a second position.

FIG. 6a is a cut-away view of an embodiment of cannula 100 having an angling device 140.

FIG. 6b is a cut-away side view of the apparatus illustrated in FIG. 6a in which the retractor 112 is extended and the angling device 140 is actuated.

FIG. 6c is a cut-away side view of the angling device embodiment in which the angling device 140 is in a separate lumen from the retractor 112.

FIG. 7a is a cut-away side view of a twistable retractor 112 in a straight position.

FIG. 7b is a side view of the retractor 112 of FIG. 7a.

FIG. 7c is a cut-away side view of twistable retractor 112 in a crossed position.

FIG. 7d is a side view of the retractor 112 of FIG. 7c.

FIG. 8a is a cut-away side view of the handle 104.

FIG. 8b is a cut-away side view of an alternate embodiment of handle 104.

FIG. 9a is a side view of cradle 116.

FIG. 9b illustrates a first alternate embodiment of cradle 116.

FIG. 9c illustrates multiple views of a second alternate embodiment of cradle 116.

FIG. 9d illustrates multiple views of a third alternate embodiment of cradle 116.

FIG. 9e illustrates multiple views of a fourth alternate embodiment of cradle 116.

FIG. 9f illustrates multiple views of a fifth alternate embodiment of cradle 116.

FIG. 9g illustrates multiple views of an embodiment of cradle 116 having a spur.

FIG. 10a illustrates a top view of an embodiment of the cradle 116 of FIG. 9c without a "C" ring.

FIG. 10b illustrates a side view of the cradle 116 of FIG. 10a.

FIG. 10c illustrates a top view of the cradle 116 of FIG. 9c with the "C" ring attached.

FIG. 10d

illustrates a side view of the cradle 116 of FIG. 10c.

FIG. 11 illustrates a perspective side view of cradle 312 for remotely ligating vessel.

FIG. 12 illustrates a perspective side view of cradle 312 in operation.

FIG. 13 illustrates a perspective side view of cannula 100 having a dissection cradle 312.

FIG. 14a illustrates a perspective side view of cannula 100 with retractor 112 extended.

FIG. 14b illustrates a perspective side view of cannula 100 with a retractor 112 retracted.

FIG. 15 illustrates a perspective side view of cannula 100 with transection device 316.

FIGS. 16a-c illustrates multiple views of tension mount 308.

FIG. 17 is a flowchart illustrating the process of remote ligation of a vessel in accordance with the present invention.

FIG. 18 is a flowchart illustrating the process of remote ligation and vessel harvestation under gas insufflation.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates a perspective view of a preferred embodiment of cannula 100 showing retractor 112 in an extended position. Cannula 100 includes an outer housing of bioinert material such as polymed UD that may be approximately 12" to 18" in length. The proximal end of the cannula 100 is disposed in handle 104 that includes a button 106 which is coupled to retractor 112 for controlling the translational movement of retractor 112, as described in more detail below.

The distal end of the cannula houses a retractor 112, and optionally an endoscope 126 and a surgical tool 120, described below. FIG. 2a illustrates the retractor 112 in more detail. In one embodiment, retractor 112 is formed of resilient wire which has a smooth bend intermediate to a first portion 110 and a second portion 114 of the retractor. The retractor 112 is described as having two portions for ease of description, although the retractor 112 may be formed as an integrated structure. However, retractor 112 may also be manufactured from two separate portions 110, 114 that are coupled together. The first portion 110 of the retractor 112 is positioned within the cannula 100 with the axis 111 of the first portion 110 approximately parallel to the axis 101 of the cannula 100. The second portion 114 is positioned to bend away from the central axis 101 of the cannula. The angle 117 of displacement between the axis 115 of the second portion and the central axis 101 of cannula 100 may be any angle from zero to 180 degrees. The second portion 114 includes a dissection cradle 116 at the distal end of the second portion 114. The retractor 112 may be formed of bioinert material such as stainless steel, or a polymer such as nylon or polyetherimide, or other appropriately strong and springy plastic. In one embodiment, the retractor 112 includes a coating for lubrication, insulation, and low visual glare using, for example, parylene or nylon 11.

FIG. 2b illustrates the retractor 112 formed with two legs. The legs 141, 142 of the retractor 112 at the distal end form the dissection cradle 116 in a loop or "U" shape, as shown in FIG. 2a. The top portion 144 of the U-shaped bend is preferably flattened to provide additional surface area for atraumatically supporting a vein 118 or vessel of interest. The side arches 128 of the dissection cradle 116 are used for skeletonizing or dissecting the vein from the surrounding tissues, as well as acting as walls to keep the vessel captured within the arch. The several embodiments of dissection cradle 116 are described in more detail below.

FIG. 3a illustrates a perspective view of the cannula 100 in accordance with the present invention with the retractor fully extended, holding a saphenous vein 118, and also illustrates an external surgical tool 120 disposed adjacent the cannula 100 for performing a surgical operation, for example, severing a tributary or side branch of the vein 118. The vein is positioned within the side arches 128 of the cradle 116. The dissection cradle 116 may be used to cradle

a vein, vessel, tissue or organ of interest, and surgical tool **120** may be any surgical tool suitable for performing a surgical procedure near the dissection cradle **116**.

FIG. **3b** illustrates a perspective view of cannula **100** in an embodiment in which the surgical tool **120** is positioned within the cannula **100**, and an endoscope **126** is present. In this embodiment, cradle **116** preferably overlays the endoscope **126** with sufficient clearance to facilitate relative movements thereof. However, the endoscope may also be located adjacent the surgical tool **120**. In one embodiment, endoscope **126** is positioned with cannula **100** to allow a clear field of view upon extension of the retractor **112**. Surgical tool **120** is illustrated as scissors, used to sever a tributary or side branch of a saphenous vein **118**. In this embodiment, surgical tool **120** is maximally displaced from the cradle **116** at the cannula end **122**. More specifically, as shown in FIG. **3c**, the “U”-shaped loop **129** of the cradle **116** is closest to the surgical tool **120**. This ensures that a vein **118** or other tissue of interest is retracted away from the surgical tool **120** to facilitate manipulating the surgical tool **120** relative to the side branch or other tissue.

FIG. **4a** is a cut-away top view of cannula **100**. The retractor **112** is slidably positioned within minor lumens **113** along the length of the cannula **100** within close tolerances in order to position the retractor **112** stably within the cannula **100**. For example, in one embodiment retractor legs **141**, **142** are approximately 0.045 inches in diameter and the lumens **113** encasing the legs **141**, **142** are approximately 0.080 inches in diameter, as friction between the legs of the retractor **112** and the lumens **113** holds the retractor stably within the cannula. This configuration restricts rotational movement of the retractor to provide more stable retraction as compared with conventional retractors. The legs **141**, **142** of the retractor **112** are formed of flexible, resilient material and are retained within the lumen **113** in substantially straight or flat orientation, but may return to a material bend or curve, as illustrated in FIG. **5a**, as the retractor **112** is extended from the distal end of the cannula **100**.

The leg **141** of the retractor **112** passes through a sliding gas or fluid seal **130** at the proximal end of the lumen **113**. The leg **141** of the retractor **112** passes out of the cannula **100** and into handle **104** for attachment to a slider button **106** for facilitating translational movement of the retractor **112** from the proximal or handle end of the cannula **100**. However, other types of control devices such as knobs, grips, finger pads, and the like may be linked in conventional ways to the retractor **112** in order to manually control the translational movement of retractor **112**. In one configuration, the proximal end of leg **141** is bent relative to the axis of the cannula, and the button **106** is attached to the bent position of the leg **141** to facilitate moving the button **106** and the retractor **112** translationally under manual control. The button **106** preferably includes lateral grooves to prevent finger or thumb slippage during sliding manipulation of the retractor **112**.

Thus, in the operation of a preferred embodiment, a user actuates the slider button **106** to extend retractor **112** out of the lumen **113** at the distal end of the cannula **100**. In one embodiment, the resilient retractor **112** is formed in a smooth bend, as shown in FIG. **2a**, and gradually deflects away from the central axis **101** of the cannula **100** as the retractor is extended. Upon encountering the target vessel or tissue of interest, the vessel is restrained in the cradle **116**, and a lateral resilient force is exerted on the target vessel in a direction away from the cannula. The vessel is thus pushed away from the axis of the cannula **100**, isolating it from surrounding tissue or adjacent vessels such as tributaries or

side branches. As a tributary is thus isolated, a surgical tool **120** such as cauterizing scissors may be safely employed to operate on the tributary without harming the saphenous vein **118**. When retracted into the cannula **100**, the retractor **112** is again resiliently straightened or flattened.

In an alternate embodiment as illustrated in FIGS. **5a** and **5b**, a sliding tube **132** is added to provide operational versatility to cannula **100**. In a first position, the sliding tube **132** is retracted and the retractor **112** protrudes from the distal end at an angle with respect to the central axis **101** of the cannula **100**. In a second position, the sliding tube **132** is extended out, temporarily straightening the retractor **112**. As illustrated in FIG. **5a**, a sliding tube **132**, in a first position encases the retractor **112** up to the point at which the retractor **112** curves away from the central axis **101** of the cannula thus allowing the retractor **112** to displace and isolate a target vessel. The proximal end of the sliding tube **132** is linked to button **107** for translationally moving retractor **112** as well as actuating the sliding tube **132**. In one embodiment, as illustrated in FIG. **5a**, the sliding tube **132** is in a first position with the button **107** in an upright position. A spring **134** is coupled between a support structure **135** and the proximal end **137** of the sliding tube **132**. In the first position of sliding tube **132**, the spring **134** is extended fully and exerts little or no force on the sliding tube **132**. Of course, sliding tube **132** may be manually manipulated without linkage to a button **107**.

To extend the sliding tube **100**, button **107** is pushed down. As illustrated in FIG. **5b**, the button **107** has a cam surface **136** which pushes on the proximal end **137** of the sliding tube **132** as the button **107** is pressed. The sliding tube **132** is pushed forward, overcoming the resilient force of spring **134**, to encase the retractor **112** and decrease angle **117** between the distal end of the retractor **112** and the central axis **101** of the cannula **100**. Upon releasing the button **107**, the spring force urges the proximal end **137** of the sliding tube **132** back toward the first position against button **107**. The sliding tube **132** is formed of material having sufficient strength to force the retractor **112** to straighten out the angle **117**, and the retractor **112** is formed of resilient material having a sufficient flexibility to straighten out the angle **117** in response to a tube **132** being slid over the retractor **112**, but having sufficient rigidity to cradle and dissect a target vessel. Resiliency of the retractor **112** ensures return to the downwardly-curved shape after being released from tube **132**. Thus, in accordance with this embodiment, a user may employ the curved retractor for certain applications and employ the straightened form for other applications. A manual actuator may be configured in other ways than button **107** to extend the sliding tube **132** in response, for example, to being pulled up instead of pushed down.

Another embodiment employs a retractor **112** which has a naturally straight shape. As illustrated in FIGS. **6a** and **6b**, an angling device **140** is disposed between the distal end of the retractor **112** and the proximal end of the cannula. The angling device **140** may be positioned within the same lumens **113** as the retractor **112** and preferably may comprise two wires coupled to points below the cradle **116** of the retractor **112** substantially in parallel positions on each of the legs **141**, **142**.

Upon extending the retractor **112** using button **106**, the angling device **140** is extended with the retractor **112**. The angling device **140** is coupled to a handle **145** at the proximal end of the cannula **100** to facilitate establishing an angle in the retractor **112** by pulling with a backward force on the angling device **140**. As illustrated in FIG. **6b**, after the

retractor **112** is extended, the angling device **140** is actuated and a bend is created in the retractor **112** as the backward force exerted on the distal end of the retractor is exerted against the relatively fixed position of the retractor legs **141**, **142** disposed within the lumens **113**. As shown in FIG. **6c**, the angling device **140** may also be located in a separate lumen **202** from the retractor **112** with part of the angling device **140** positioned outside of the cannula **100** when the retractor **112** is in the retracted position.

FIG. **7a** illustrates another embodiment of cannula **100** in which the retractor **112** is pre-formed with one leg **141** of the retractor **112** bent at an angle at its proximal end skewed to the axis of the distal end of the other leg **142**. The bent portion of the leg **141** may be linked to a sliding knob **144** for convenient manual manipulation of this embodiment of the invention. Upon sliding the knob **144**, the leg **142** coupled to knob **144** is twisted rotationally. The two legs **141**, **142** of retractor **112** are coupled together via cradle **116**. The axis of the second portion of the retractor **112** in the first position is at a first angle **117** to the axis of the cannula **100**, as shown in FIG. **7b**. As knob **144** is moved, leg **141** is rotated and crosses under leg **142**, as shown in FIG. **7c**. This causes cradle **116** to flip 180 degrees and bends the retractor **112** at a second angle **119**, as shown in FIG. **7d**. Thus, if a vessel is disposed on one side of cradle **116** or cannula **100** while the retractor **112** is in the first position, then upon rotating the knob **144**, the vessel is transported to the other side of the cannula **100**. This allows the user to isolate the vessel by simply actuating knob **144**.

FIG. **8a** illustrates a cut-away side view of button **106** on the handle **104** of cannula **100**, with an endoscope **126** positioned within cannula **100**. As mentioned above, button **106** is coupled to one leg **141** of the proximal end of retractor **112**. Sliding the button **106** in groove **146** translationally moves the retractor **112**. Groove **146** is preferably minimally wider than the shaft of button **106** to minimize excessive horizontal movement of button **106** while still allowing smooth translational movement of button **106**. As illustrated in FIG. **8b**, the button **106** may include locking or ratcheting teeth **152** to give tactile feedback of its location, and to positively retain the button and the associated leg **141** in an extended or retracted position. Several mating teeth **148** are located underneath groove **146**, and a spring member **150** is attached to button **106** to exert pressure against the base of groove **146**, to engage mating teeth **148**, **152**. When a force is applied on the top of button **106**, the interlocking sets of teeth are disengaged and button **106** can move freely. Upon achieving the desired extension or retraction of the leg **141**, button **106** is released and is retained place by the engaged teeth **148**, **152**.

FIG. **9a** illustrates a top view of cradle **116** in an embodiment in which the cradle **116** is formed by two legs **141**, **142** of retractor **112**. The distal end of the legs form "U"-shaped side guides. The top **144** of the distal portion of the "U" is preferably flattened. This provides atraumatic support for the target vessel retained within cradle **116**. Additionally, by minimizing the thickness of distal portion **144**, contact with other devices in close proximity with retractor **112** is minimized.

The cradle **116** may have other effective shapes, for example, as illustrated in FIG. **9b** in which a "C" ring element is attached to legs of the cradle **116**. The "C" ring may have a small hole **200** in one side with an axis approximately parallel to the axis of the retractor **112**. This hole **200** is used to hold suture or other ligating materials, and may also be used as a knot pusher. As shown in FIGS. **10a** and **10b**, in an alternate embodiment of the embodiment

of FIG. **9b**, the retractor **112** is formed and flattened and a "C"-shaped ring is coupled to the retractor **112** by, for example, gluing or molding the "C" ring to the distal end of the retractor **112**, as shown in FIG. **10c** and **10d**.

Referring back to FIGS. **9c**, **9d**, and **9e**, the side guides of the cradle may include a loop **129** in a "V" shape, an arced "U" shape, or a semi-circular shape. In one embodiment, as illustrated in FIG. **9f**, the retractor **112** has only one leg **141**, and the cradle **116** is formed by the leg **141**. A stopper **160** is coupled to the end of the leg **141** to serve as a guide to retain the target vessel, and add a blunt surface to the end of the wire, for example, for pushing and probing tissue. FIG. **9g** illustrates a retractor **112** having a spur **204** formed in one or both legs **141**, **142** for allowing the retractor **112** to be used for dissection. Sinusoidal, half-sinusoidal, and other geometric configurations may be used equally effectively as the shape of loop **129** in accordance with the present invention.

FIG. **11** illustrates an alternate dissection cradle **312** for use in remote vessel ligation. Remote vessel ligation as discussed above is necessary to provide hemostasis to a vessel or other tissue after the vessel has been transected. In accordance with the present invention, hemostasis is accomplished by tightening suture formed in a loop adjacent the point of transection of the vessel. However, it is preferable to provide hemostasis to the vessel without incising the body a second time at the point of transection. The cannula **100** and dissection cradle **312** provide this functionality.

At the distal end of the retractor **312**, a shoulder part **300** is preferably formed of a rigid plastic encapsulating the distal end of the retractor **112**. A curved channel part **304** is attached to the shoulder **300**. The curved channel **304** is formed in the shape of a "C" as shown. The curve of curved channel **304** exposes a portion of the distal face of the shoulder **300**, upon which a suture loop **328** may be abutted, as shown in FIG. **12**. Other shapes, such as those shown in FIGS. **9a-e**, may also be used as curved channel **304**.

FIG. **12** illustrates the manner in which the suture loop **328** is transported safely to the point of transection. The loop **328** is formed as a slipknot, which may be cinched tighter by exerting a backwards force on the free end of the suture **320**. The suture loop **328** is tied around the vessel and the curved channel part **312**, and is abutted against the shoulder **300**. Next, the loop **328** is tightened onto the curved channel **304** by pulling back on the free or proximal end of the suture **320**. The loop **328** is tightened sufficiently to permit safe advancement, but is provided with sufficient slack to allow displacement of the loop **328** onto the vessel adjacent the point of transection upon retraction of the retractor **312** into the cannula **100**.

One embodiment of the present invention for exerting a backward or disengaging force on the loop **328** is shown in FIG. **13**. FIG. **13** illustrates a tension mount **308** attached to cannula **100** for providing secure transport of the suture **320** to the surgical site of interest and for providing a controlling mechanism for tightening the suture loop **328** around the vessel when ligation is desired. The tension mount **308** is also formed of rigid plastic with some flexibility to allow other surgical tools **120** (not shown) to extend beyond the distal end of the tension mount **308**, and to allow atraumatic advancement of the tension mount **308** through the body. The distal end of the tension mount **308** includes a hole **324** through which the suture is threaded to tighten the suture loop **328**. The distal end of the tension mount **308** protrudes toward the central axis of the cannula **100**. This ensures that the vessel and the suture will be in the optimal position for

transection or cutting after the loop 328 has been displaced onto the vessel. Additionally, the forward angle of the tension mount 308 also ensures that the loop 328 will be displaced onto the vessel upon retraction of the retractor 312, as discussed in greater detail below. The length of the tension mount 308 is chosen to allow the cradled vein to remain in endoscopic view upon advancement. Alternatively, a long knot pusher may be used in place of tension mount 308. The suture 320 is looped around the vessel and the curved channel 304, previously described. However, the free end of the suture 320 is threaded through a hole in the long knot pusher disposed within the cannula 100. The cannula 100 and knot pusher are advanced to the point of transection. Displacement of the loop 328 occurs by advancing the knot pusher while maintaining the position of the dissection cradle 312 relative to the vessel. After the loop 328 is displaced onto the vessel, the loop 328 is tightened by pulling backward on the suture 320. The long knot pusher may contain a lumen which runs the length of the cannula 100 or it may contain a shorter lumen which starts at the tip of the cannula and exits a side of the cannula 100 after a short distance proximally.

FIG. 14a illustrates the operation of the cannula 100 which has a tension mount 308. The cradle 312 holds a vessel 330. The vessel 330 is safely cradled in the curved channel 304 as the cannula 100 is advanced. The suture 320 is threaded through the hole 324 disposed in the distal end of the tension mount 308. The distal end of the suture 320 is then formed into a suture loop 328 around the vessel 330, and is abutted against the shoulder 300. In this embodiment, the proximal end of the suture 320 is wrapped around a cleat 332 on button 106 at the proximal end of the cannula 100. The loop 328 is tightened around curved channel 304 by winding the proximal end of the suture 320 around the cleat 332 which has the effect of pulling on the suture loop 328 and cinching the knot tightly around the curved channel 304 against the shoulder 300. The suture loop 328 may now be safely advanced to the surgical site as excessive slack does not occur in the loop 328, which would cause the loop 328 to be dislodged from the cradle 302. In an alternate embodiment, the loop 328 is tightened responsive to the sliding of the button 106. The button 106 has a lock with a release mechanism which restricts the sliding of the button 106. When the loop 328 requires tightening after displacement onto the vessel, the lock is released and the button 106 is retracted. This embodiment ensures that the surgeon does not accidentally dislodge the loop 328 from the shoulder 300 by prematurely retracting the retractor 312 into the cannula 100.

Upon reaching the site of interest, the loop 328 is displaced onto the vessel 330 by sliding a manual controller backwards, causing the retractor 112 to retreat to an axial position. In the embodiment of FIGS. 14a and b, the loop 328 is displaced by sliding the button 106 backwards. Upon sliding the button 106 backwards, as shown in FIG. 14b, the cradle 312 is retracted into cannula 100, causing the loop 328 to be forcibly displaced from the shoulder 300 of the dissection cradle 312 onto the vein 330 at the desired location.

After displacement onto the vessel 330, a knot tightener is then used to tighten the suture loop 328 onto the vessel 330 to provide hemostasis. In the embodiment of FIGS. 14a and b, the loop 328 is tightened onto the vessel 330 as the proximal end of the suture 320 is wound around the cleat 332. The proximal end of the suture 320 could also simply be detached from the proximal end of the cannula 100, and the loop 328 tightened by pulling on the free end of the

suture 320. Alternatively, the loop 328 may be tightened by fixing the proximal end to the button 106. Sliding the button 106 towards the proximal end of the cannula 100 exerts a backwards force on the loop 328, tighten the loop 328.

FIG. 15 illustrates the use of the transection instrument 316 in accordance with the present invention. The transection instrument 316 is preferably endoscopic shears disposed within cannula 100. The shears 316 are positioned between tension mount 308 and cradle 312. After the vessel 330 has been ligated as described above, the shears 316 are extended to transect the vessel. As the vessel is tied by the suture 320 which passes into the tension mount 308, the vessel is thus placed within easy reach of the blades of the shears 316. The tension mount 308 is formed with a slight bend toward the center of the cannula 100 to facilitate keeping the vessel 330 within the apex of the open blades of the shears 316. After transecting the vessel 330, the vessel 330 will fall away as shown in FIG. 15. The suture 320, however, is now within the apex of the open blades of the shears 316. The shears 316 are then extended again and used to cut the suture 320. The ligated vessel 330 remains in the surgical site, and the graft is able to be removed through the first and only incision.

FIGS. 16a-c illustrates multiple views of tension mount 308. FIG. 16a illustrates tension mount 308 attached to a collar 336. The collar 336 allows the cannula 100 to be used without a tension mount 308 for the initial transection operation in which the tributaries of the vessel 330 are transected to allow the main length of the vessel to be extracted from the body. For this initial transection operation, the tension mount 308 may interfere with this procedure, and thus should be removed.

The collar 336 of the tension mount 308 has proximal and distal ridges 338, 339 disposed on its inner surface. FIG. 16b illustrates in greater detail the proximal ridge 338 which mates with ridges disposed on the cannula surface. As shown in FIG. 16c, the distal end 342 of the cannula 100 is smooth plastic or other bioinert material on which the ridged collar 336 may slide easily. Ridges 346 situated at flat or recessed portions 345 on the surface of the body of cannula 100 form edges 344 for retaining the collar 336. Upon sliding the collar 336 onto the distal end 342 of the cannula 100, the collar 336 resiliently expands and ridges 338, 339 of the collar 336 align with edges 344 of the cannula 100. Upon alignment, the collar 336 resiliently contracts and thus forms a secure fitting of collar 336 on cannula 100. When the surgeon wants to remove the collar 336, the surgeon simply twists the collar 336 to misalign the ridges 338, 339 of the collar with ridges 346 of the cannula 100, causing the collar 336 to resiliently expand again, thus allowing the collar 336 to be easily removed from the cannula 100.

FIG. 17 illustrates a method of performing remote vessel ligation in accordance with the present invention. The surgeon advances 1700 a suture loop 328 along a vessel to a remote site from incision. The suture loop 328 is displaced 1704 onto the vessel responsive to retraction of the retractor, and, responsive to exerting 1708 a backward force on the suture, the vessel is ligated.

In a further embodiment, as shown in FIG. 18, the one-incision ligation and harvesting operation is performed under gas insufflation. First, an incision is made 1800 at the desired beginning point of the graft. For example, for saphenous vein harvesting for coronary artery bypass grafting, the incision is made at the knee. Next, the cannula 100 is inserted 1804 into the incision, and the incision is sealed 1808. A tunnel is formed along the vessel by insufflating 1812 the area with gas. The suture loop 328 is safely

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advanced **1816** to the destination. For saphenous vein harvesting, the loop **328** is advanced to its origin at the saphenofemoral junction. The loop **328** is displaced **1820** onto the vessel, and a backwards force is applied **1824** to the suture **320** to ligate the vessel. The vessel is transected **1828** and the suture is cut **1832**. The vessel can now be removed **1836** from the original incision. Thus, in accordance with the present invention, only one incision is required to harvest and ligate vessel in accordance with the present invention. The use of dissection cradle **312** allows the suture loop **328** of suture **320** to be advanced safely to the surgical site without being caught on the main trunk of the vessel or side branches thereof. The tension mount **308** accurately and reliably positions the vessel for transection and the suture **320** for cutting and provides the tension required to tighten the suture loop **328** of suture **320** onto a forward shoulder of the curved channel **304** for safe advancement and tensioning as required to provide hemostatic transection and harvesting of a target vessel.

What is claimed is:

1. Surgical apparatus comprising:

an elongated cannula including a plural number of lumens extending therein between proximal and distal ends thereof;

a retractor disposed within a lumen of the cannula to extend beyond the distal end of the cannula for engaging a vessel in response to movement of the retractor within the lumen to resiliently displace the vessel away from axial alignment with the elongated cannula; and
a surgical tool supported in a lumen of the elongated cannula and extending beyond the distal end thereof for simultaneous operation with the retractor for performing a surgical procedure on the vessel engaged by the retractor.

2. Surgical apparatus according to claim **1** in which the retractor and the surgical tool are relatively movable near the distal end of the cannula to facilitate severing a portion of the vessel engaged by the retractor.

3. Surgical apparatus comprising:

an elongated cannula including a plural number of lumens extending therein between proximal and distal ends thereof;

a retractor disposed within a lumen of the cannula to extend beyond the distal end of the cannula for engag-

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ing a vessel in response to movement of the retractor within the lumen, the retractor including at least one arm slidably disposed within said lumen of the cannula that supports a cradle in lateral orientation with respect to the arm; and

a surgical tool supported in a lumen of the elongated cannula and extending beyond the distal end thereof for performing a surgical procedure on a vessel engaged by the retractor.

4. Surgical apparatus according to claim **3** in which the cradle includes a generally U-shaped segment laterally oriented with respect to the arm.

5. Surgical apparatus according to claim **4** in which the arm includes a distal portion thereof that is laterally flexible and resiliently biased away from axial alignment with the elongated cannula.

6. Surgical apparatus according to claim **5** in which the U-shaped cradle includes a recess disposed to engage a vessel therein that is aligned in the direction of the resilient bias for resiliently deflecting a vessel engaged thereby away from axial alignment with the elongated cannula.

7. Surgical apparatus according to claim **3** including a pair of arms slidably disposed within lumens of the catheter and supporting the cradle therebetween at distal ends of the pair of arms.

8. A surgical procedure performed with an elongated cannula including a retractor and a surgical tool disposed near a distal end of the cannula, the procedure comprising the steps for:

positioning the distal end of the cannula near a target vessel;

engaging the target vessel with the retractor for resiliently displacing the target vessel laterally away from axial alignment with the elongated cannula; and

simultaneously engaging a branch vessel of the displaced target vessel with the surgical tool to sever the branch vessel from the target vessel.

9. The surgical procedure according to claim **8** in which the retractor and surgical tool are selectively deployed from the distal end of the cannula for simultaneous operation to sever the branch vessel from the target vessel.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,830,546 B1
APPLICATION NO. : 10/052016
DATED : December 14, 2004
INVENTOR(S) : Albert K. Chin et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Col. 12 line 24, Claim 7, replace "catheter" with -- cannula --.

Signed and Sealed this

Seventeenth Day of March, 2009



JOHN DOLL
Acting Director of the United States Patent and Trademark Office